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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management or engineering tools to help pollution control officials achieve water quality goals through watershed management.

The development and application of mathematical models to simulate the movement of pollutants through a watershed and thus to anticipate environmental problems has been the subject of intensive EPA research for several years. The most recent advance in this modeling approach is the Hydrological Simulation Program - FORTRAN (HSPF), which uses digital computers to simulate hydrology and water quality in natural and man-made water systems. HSPF is designed for easy application to most watersheds using existing meteorologic and hydrologic data. Although data requirements are extensive and running costs are significant, HSPF is thought to be the most accurate and appropriate management tool presently available for the continuous simulation of hydrology and water quality in watersheds.

William T. Donaldson
Acting Director
Environmental Research Laboratory
Athens, Georgia

ABSTRACT

The Hydrological Simulation Program - FORTRAN (HSPF) is a set of computer codes that can simulate the hydrologic and associated water quality processes on pervious and impervious land surfaces, in the soil profile, and in streams and well-mixed impoundments. This document describes the entire application process of HSPF to demonstrate the decisions, procedures, and results that are involved in a typical application. The document is intended as a supplement to the existing HSPF user's manual and programmer's supplement. Together these three documents provide sufficient guidance for the full and intelligent use of the broad range of capabilities of HSPF.

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CONTENTS

Section **Page**

Abstract. iv
Figures vii
Tables. viii
Acknowledgments ix

1. Introduction. 1

2. Study Definition. 5
   2.1 Definition of Study Goals. 5
   2.2 Assessment of Data Availability. 7
   2.3 Assessment of Time and Resources 8
   2.4 Study Definition Process for the Iowa River Study. 12
   2.5 Summary. 15

3. Development of a Modeling Strategy. 17
   3.1 Selection of Constituents and Sources to be Modeled. 18
   3.2 Preliminary Segmentation of Land Area Based on Weather Data. 27
   3.3 Final Segmentation of the Land Area. 38
   3.4 Segmentation and Characterization of the Channel and Contributing Areas 47
   3.5 Characterization of Special Actions. 55

4. Operational Aspects of HSPF Use 57
   4.1 Steps in Running HSPF. 57
   4.2 Overview of HSPF Input 58
   4.3 Output Options 62

5. Input and Management of Time Series Data. 70
   5.1 Creation of Time Series Store (TSS). 70
   5.2 Adding Dataset Labels. 72
   5.3 Input of Data. 72
   5.4 Management of TSS Datasets 75

6. Model Parameters and Parameter Evaluation 77
   6.1 Types of Data Needed 78
   6.2 Sources of Data. 78
   6.3 General Considerations 82

7. Calibration and Verification. 84
7.1 General Calibration Procedures 84
7.2 Calibration Guidelines for Major Constituent Groups 89
7.3 How Much Calibration ? 112
7.4 Verification 114

8. Analysis of Alternate Conditions. 116
8.1 Philosophy Underlying Comparison of Alternatives. 116
8.2 Steps in the Analysis Process. 118
8.3 Examples of Analyzing Alternatives with HSPF. 119

9. References. 138

Appendices. 140
A. Sample HSPF Input Sequence 140
B. Use of the NETWORK Block to Connect the Surface and Instream Application Modules. 167
C. Equivalency Table for Selected HSPF and ARM/NPS Parameter Names. 170

FIGURES

Figure		Page
2.1	Representative HSPF Project Schedule.	13
3.1	Meteorologic and U.S.G.S. Gaging Stations in and near the Iowa River Basin.	31
3.2	Isopleths of Mean Annual Precipitation and Potential Evapotranspiration in Iowa.	32
3.3	Isopleths of Mean Annual Temperature in Iowa. . . .	34
3.4	Preliminary Segmentation of the Iowa River Basin to Account for Variability in Meteorologic Patterns and Soils Characteristics.	41
3.5	Channel Reaches and Contributing Areas for the Iowa River Basin.	42
3.6	Final Segmentation of the Iowa River Basin.	43
3.7	Iowa River Low-Water Profile.	50
4.1	Sample Short-span Display (first type) from the DISPLY Module of HSPF.	64
4.2	Sample Short-span Display (second type) from the DISPLY Module of HSPF.	66
4.3	Sample Long-span Display (annual) from the DISPLY Module of HSPF.	67
5.1	Example of User's Control Input for the COPY Module	74
7.1	Example of Response to the INTFW Parameter.	93
8.1	Frequency Curves for Simulated Ammonia and Nitrate at Marengo, Iowa.	128
8.2	Lethality Analysis of Chemical Concentration. . . .	130
8.3	Locations of the 21 Dam Sites for Power Generation in the Rio Yaque del Norte Watershed, Dominican Republic.	132
8.4	Clinton River Drainage Basin, Michigan.	134
8.5	Dunn-Wilcox Watershed	135
8.6	Hydrograph of Reach 941 for June 26, 1968 Event . .	137

TABLES

Table		Page
2.1	HSPF Release 7.0 Run Costs.	11
3.1	Constituent Hierarchy in HSPF for Instream Modeling	20
3.2	Meteorological Time Series Data Requirements for HSPF.	28
3.3	Summary of Meteorologic Data Used to Represent the Three Segment Groups of the Iowa River Basin. . . .	36
3.4	Definition of Pervious Land Segments for the Iowa River Basin.	45
3.5	Land Use in the 13 Contributing Area Subdivisions in the Iowa River Basin.	46
3.6	Reach Characteristics for the Iowa River.	54
4.1	HSPF Input Blocks and Recommended Sequence.	60
4.2	Examples of Input Blocks Required for HSPF Runs . .	61
4.3	Operations Performed by the GENER Module of HSPF. .	69
6.1	Types and Sources of Data Needed to Use the Various Sections of the HSPF Application Modules. .	80
8.1	Selected Alternatives, Associated HSPF Assumptions, and Suggested Input Modifications. . .	120
8.2	Selected BMP Scenario for Simulation on the Iowa River Basin.	123
8.3	Comparison of Edge-of-Stream Loadings for Base Conditions and BMP Simulations in the Iowa River Basin	124
8.4	Comparison of Loadings in the Iowa River at Marengo for Base Conditions and BMP Simulations . .	126
8.5	Lethality Analysis of BMP Scenario for Alachlor in the Iowa River at Marengo, Iowa.	131
8.6	Comparison of Maximum Flows for Reaches with Channel Storage	137

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Among the authors, Mr. Anthony Donigian was the Project Manager with overall responsibility for technical direction, supervision, and review. He was also the major author of the final section of this document, analysis of alternate scenarios. Among the authors, Mr. John Imhoff was the Task Leader for this project and initial author for the sections describing procedures for study definition, development of a modeling strategy, parameter evaluation, and calibration and verification. Mr. Brian Bicknell was responsible for the sections pertaining to the operational aspects of HSPF and the input and management of time series data. Mr. Jack Kittle provided significant technical review and guidance, and was also the key source on all HSPF operational questions.

In addition to the authors, several other individuals at Anderson-Nichols were active in preparation of this document. Ms. Kathyrn Lahanas and Ms. Mary Maffei provided report typing and text editing throughout the project, and Ms. Virginia Rombach prepared the report charts and figures, and assisted in final preparation of the document. The dedication and efforts of these individuals contributed to the success of the project.

SECTION 1

INTRODUCTION

This document describes the entire application process of the Hydrologic Simuiation Program - Fortran (HSPF) using the Iowa River Basin Study (Imhoff et al., 1983) to demonstrate the decisions, procedures, and results which are involved in a typical HSPF application. The document is intended as a supplement to the existing User's Manual (Johanson et al.,1984) and Programmer's Supplement (Johanson et al.,1979). Together these three documents provide sufficient guidance to allow the user to make full and intelligent use of the broad range of capabilities contained in HSPF.

The User's Manual provides instructions for building input sequences and explains the basis for the simulation algorithms. Included in the User's Manual are an explanation of basic model concepts, programming standards and practices, a visual table of contents of program components, functional descriptions of subprograms, and format information for the User's Control Input.

The Programmer's Supplement permits the user to follow the inner workings of the model. Program code, in the form of IBM pseudocode (IBM, 1974), data structures and file structures, and sample input sequences and results are included. The Programmer's Supplement is contained on magnetic tape.

While the User's Manual and Programmer's Supplement provide a systematic and comprehensive description of model contents and operational procedures, many questions which are critical to the intelligent use of HSPF are left unanswered. Additional guidance is needed to answer such user questions as:

(1) How can I develop a modeling strategy which will address the problems I need to analyze?

(2) What kinds of data do I need for my modeling effort, and where can I get this data?

(3) What model parameters are most critical to my application, and how do I develop the most reasonable values for these parameters?

(4) What is involved in the model calibration and verification process, and how much calibration effort is necessary before I can use the model to analyze my problems?

(5) Once the calibration and verification process is complete how can I use the model to evaluate the effects of alternate practices?

(6) How can I use the model's capabilities to provide me with results which are the most informative and the most useful for interpretation and presentation?

The purpose of this document is to answer these and related questions concerning the application of HSPF to engineering and planning studies. The discussion of the application process is divided into the following seven major steps which are necessary to perform a complete model application:

- Study Definition
- Development of a Modeling Strategy
- Learning the Operational Aspects of HSPF Use
- Input and Management of Time Series Data
- Parameter Development
- Calibration and Verification
- Analysis of Alternate Scenarios

The "study definition" process involves (1) identification of the questions which the model application must answer, and determination of the level of detail required to answer these questions; (2) assessment of the availability of supporting data and its usefulness to the modeling effort; and (3) comparison of the time and money available to perform the modeling effort with estimates of resources required for the intended application.

Successful application of HSPF to a study area requires the development of a simulation plan or strategy, based on characterization of the area with regard to meteorologic conditions (and spatial variability), soils characteristics, topography, land use, pollutant sources, available historic data, etc. The purpose of this section is to outline the general characterization process.

An important step in applying HSPF is familiarizing oneself with the mechanics of the model so that the input sequences necessary to build the time series data base (Time Series Store) and execute simulation runs can be developed. The goal of this section is to provide an overview of considerations involved in running HSPF and developing input sequences, and to direct the user to the proper places in the User's Manual for additional information.

All HSPF simulation runs involve the use and/or generation of data in the form of time series. This section describes the storage, retrieval and management of time series data using HSPF utility routines, stand-alone programs and a large random access file known as the Time Series Store (TSS).

Parameter development focuses on the process-oriented parameters needed as input to the application modules of HSPF. Since the model is designed to be applicable to many different watersheds and water systems, these parameters provide the mechanism to adjust the simulation for specific topographic, hydrologic, edaphic, land use, and stream channel conditions of a particular area. The parameter development section is designed to familiarize the user with the types of data which are needed for parameter evaluation and to direct the user to existing data and documents which will prove useful in the evaluation process.

Calibration is the process of adjusting selected model parameters within an expected range until the differences between model predictions and field observations are within selected criteria for performance. It is required for parameters that cannot be deterministically evaluated from topographic, climatic, edaphic, or physical/chemical characteristics. Verification is the complement of calibration; model predictions are compared to field observations that were not used in calibration. In essence, verification is an independent test of how well the model (with its calibrated parameters) represents the important processes occurring in the natural system. The calibration/verification section provides recommended procedures and guidelines for the major sections and constituents of HSPF.

Because of the comprehensive scope of HSPF, once it has been applied (i.e., calibrated/verified) to a watershed system it can be subsequently used to analyze a variety of proposed or projected alternative conditions. In this process the calibrated/verified model is used to project changes in system response resulting from a proposed alternative; this alternative is represented in HSPF by adjustments (changes) to model input, parameters, and/or system representation (e.g., interconnection of PLSs and stream reaches). This section discusses the basic philosophy underlying the use of HSPF for analysis of alternatives, enumerates the various steps involved in this process, provides guidance in analyzing selected alternatives, and describes related examples drawn from past experience with HSPF and/or predecessor models.

In describing the general application process, we make numerous references to the Iowa River Basin Study, which was a preliminary application of HSPF to model water quality and the effects of agricultural best management practices (BMPs). While no one example application can serve to demonstrate the extensive capabilities and potential diverse applications of the model, the Iowa River project illustrates many of the decisions, procedures, and results involved in using HSPF.

At each step in the application process we will first explain what needs to be done; then explain how it was done in the Iowa River project; and finally discuss additional considerations and/or actions which may be necessary for different types of applications. Thus, while the previously existing documentation instructs the user on HSPF model contents and operational procedures, this document is primarily designed to instruct the user on how to use the model to analyze engineering and planning problems in an intelligent manner.

The user should note that the Iowa study required the full range of HSPF capabilities from data management to pesticide runoff and soil simulation to instream sediment transport and pesticide fate modeling. Many user problems and potential applications will require only subsets of HSPF capabilities and significantly less resources.

SECTION 2

STUDY DEFINITION

A realistic assessment of study goals and resources at the beginning of a modeling project is critical to the development of an effective modeling strategy and an appropriate data base. In fact, project goals and resources will affect every step of the modeling process. A reasonable division of time and effort between the individual steps of a complete model application can only be achieved by careful consideration of the required end-products of the project and the time and money available to produce these end-products. The "study definition" process can be divided into three major tasks:

(1) Identify the questions which the model application must address, and determine the level of detail and model accuracy required to analyze and answer these questions.

(2) Assess the availability of supporting data and its usefulness to the modeling effort.

(3) Compare the time and money available to perform the modeling effort to guidelines for the effort and costs involved in an HSPF application as outlined in this document.

Each of these three tasks is considered in more detail below.

2.1 Definition of Study Goals

Clearly defined study goals are needed every step of a model application. Quite often the goals stated at the beginning of a modeling study are too ambitious or too vague. A study workplan may call for an "evaluation of watershed water quality" or a "complete investigation of hydrologic resources." Without further refinement, such goals do not provide the model user with a clear understanding of what information is needed from the model application. As an example, consider a study which calls for an evaluation of the effects of tertiary treatment of domestic wastewater on the quality of downstream receiving waters. Given that HSPF is capable of modeling nearly 20 individual water quality constituents, it is essential that the modeling effort be restricted to critical constituents based on an understanding of (1) the constituents which are most affected by the treatment practice and (2) the constituents which exert the most influence on the overall quality of the receiving waters. If in this case the study goal can be refined and stated as "an evaluation of the effects of tertiary treatment on concentrations of dissolved oxygen, BOD, ammonia, and nitrate in receiving waters," considerable effort can be saved in development of the modeling strategy, data acquisition, parameter evaluation, etc.

While it is wise to acquire and examine all existing data which could prove useful to a modeling effort, it is essential to concentrate one's effort from the beginning of the study on data pertinent to the critical constituents which will be modeled. Development of data for constituents which will not be modeled can often squander time and resources needed at later stages of the model application. Further detail on selecting appropriate constituents is provided in Section 3.1.

Many of the issues involved in properly defining a study are related to requirements for spatial or temporal definitions, or to the level-of-detail needed to answer the study questions. Early recognition of the spatial and temporal definition required in the model representation assures the development of an appropriate modeling strategy. Comparison of a "wasteload allocation study" to a "watershed water quality study" serves to illustrate the importance of recognizing spatial definition requirements.

Wasteload allocation study.
The goal of such a study is to determine an equitable distribution of chemical loadings to the receiving waters from existing point sources in a watershed. The resulting composite loadings must not violate water quality standards at any point along the channel system. To perform such a study it is necessary to analyze the effects of each major point source individually; and thus, detailed data on point source contributions and channel characteristics are required. Both factors are pertinent to the development of the model representation and the model data base.

Watershed water quality study.
The goal of a watershed-oriented study might be to assess the overall chemical loadings at the downstream terminus of a stream or river. For such a study, a number of simplifications can be made in the representation of point loads. For example, channel reaches can be defined based on

such factors as hydrogeometric and hydraulic characteristics and/or reaction rates of critical constituents Following the definition of the reach system, point source data from all contributions to a reach can be combined without significantly affecting model results at the downstream terminus.

Understanding the requirements for temporal definition in a study can have an equally significant role in development of the modeling strategy. For example, the importance of timing of flow, and hence magnitude of peak flows, to study results may determine whether or not hydraulic routing is required as a component of the modeling effort. A study to determine expected annual runoff at a potential reservoir site may not require stream routing of runoff, because determination of the maximum instantaneous flow will not influence to the study results. On the other hand, accurate representation of peak flows may be critical to a design study for a flood control structure.

Precise statement of study goals with careful consideraton of the spatial and temporal modeling detail necessary to answer the critical study questions will vastly improve the likelihood of a successful model application. Additional issues concerning level-of-detail are critical to every step of the simulation process. For example, the model user must assess the appropriate detail for representing the constituent sources and processes which are modeled. Only those constituent sources and processes which are likely to have a significant effect on study results should be included in the modeling effort. The goal is to achieve a suitable fit between the planned modeling effort and the data, time, and money available to perform the study. The role that project resources play in determining realistic and realizable study goals is discussed in the following sections (Section 2.2 and 2.3).

2.2 Assessment of Data Availability

Effective use of HSPF requires considerable data to characterize watershed land use, soils, and meteorology; for model applications in which channel processes are important, additional data on streamflow, channel geometry, and instream chemical concentrations are necessary. Sufficient knowledge of the physical, chemical, and biological characteristics of the study area must also be available to develop numerous parameter values. Subsequent sections of this document will provide guidelines for the proper selection and use of all these different kinds of data. The purpose of this discussion is to emphasize that a model user must collect and assess available data at the beginning of a study in order to assure that sufficient data exists to allow confidence in model results.

Model results can be only as good as the data used to apply the model. If the data used as input to HSPF is accurate and comprehensive, the model user can have more confidence that the model representation is appropriate for the study area. When simulation results have been produced, they must be compared to additional data such as observed streamflow or instream chemical concentrations. A good comparison between simulated and observed values indicates that the model algorithms adequately represent the critical processes in the study area. Unfortunately, a modeler never has all the data needed to fully represent the study area and verify simulation results. Filling in missing input data for a study area based on general knowledge, data from other watersheds, and previous modeling experience can provide reasonable simulation results in many cases. The degree of confidence given to these results should reflect the amount of missing data, the reasonableness of the assumptions used in filling data gaps, and the amount of observed data available to verify the simulation results.

Scarcity of observed data to verify simulation results can significantly weaken confidence in model results and hence the achievement of study goals is threatened. At the initial stage of model application, it is critical that the user assess whether or not adequate observed data exist to verify model results. Data must represent the spatial and temporal variations in flow and/or chemical loadings resulting from the combined meteorologic, hydrologic, chemical, and biological processes of the study area. While an adequate record of meteorologic and hydrologic data exists for most areas, water quality data are frequently of poor quality due to infrequent sampling, time-composited samples, etc. If insufficient data exist to verify the model results, a supplementary sampling program should be considered. In many cases a modeling study may not achieve its goals if simulation results cannot be substantiated by observed data.

2.3 Assessment of Time and Resources

Data is not the only resource which is important to defining and analyzing study goals - the time and money available to perform the study are equally critical. This section provides preliminary guidelines for the time and costs involved in modeling studies using HSPF.

HSPF is a new model, with its initial release occurring in 1979. While a number of HSPF applications are in progress, few studies are complete; consequently information on time and costs associated with model application is limited to a few pilot studies. The potential model user should use the guidelines presented below to make a preliminary assessment on whether or not the planned model application can be performed within the time and budget available. The guidelines were derived primarily from modeling studies performed by staff who were heavily involved in the HSPF model development; lack of familiarity with the model will increase the time and effort required for model application. Three topics will be discussed:

(1) Amount of time and effort required for representative applications (including computer costs)

(2) Relative effort involved in the seven steps of model application

(3) Relative timing for performance of the seven application steps.

The following estimates of level-of-effort, computer costs, etc., required for representative applications are based upon two recent pilot applications: the Four Mile Creek Basin near Traer, Iowa, (Donigian et al., 1983b) and the Iowa River Basin located in central Iowa. Both studies involved land surface and instream modeling of runoff, sediment, and chemicals on agricultural watersheds. In the Four Mile Creek application, detailed calibration and verification of the model was performed for three small field sites each representing a separate land use activity: corn and soybean cropland and pasture. Simulation periods were six months for pesticide calibrations and twelve months for agricultural nutrients. Subsequently, the results were extrapolated to the entire watershed where the same constituents were modeled on three land segments and the results used as loadings to an eight-reach stream system. Less detailed calibration was performed at the watershed level where the simulation periods ranged from four months to thirty months, and two separate agricultural practice scenarios were simulated.

In the Iowa River study, the methodology developed on Four Mile Creek was extrapolated to the 7200 sq. km. Iowa River Basin to demonstrate its applicability on a large river basin. For modeling purposes, the study area was divided into nine pervious land segments in order to represent variability in meteorology, topography, soils, land use, and agricultural practices and chemical applications (see Section 3). Runoff and associated loadings of sediment, inorganic nitrogen, and one pesticide were simulated for a five year period and were used as input to a thirteen- reach channel system. Hydraulic routing and instream chemical reactions were simulated for the 300 kilometers of the Iowa River upstream of Marengo, Iowa. The simulation was limited to approximately six calibration runs for hydrology and sediment; full scale simulation runs for inorganic nitrogen and pesticide were performed for two different scenarios without calibration due to lack of observed data.

As an aid to the user in projecting computer costs, Table 2.1 presents the actual execution time and costs for representative one-year simulation runs from a number of applications. It is important to remember that these run costs are highly dependent on the computer rate structure, output options such as plots and displays, and other factors. The user should note carefully what is included in each of these run descriptions when estimating his own computer costs. In addition, a significant fraction of the computer costs incurred by a user (and not considered in Table 2.1) may be associated with input sequence development during interactive sessions at a computer terminal.

A major consideration in any application is the division of the available resources among the tasks to be performed. Shown below is a representative breakdown of the application effort into the steps discussed in Section 1, through calibration and verification; the analysis of alternatives is excluded because the effort will be highly dependent on the projected use.

TASK	% EFFORT
• Problem Definition	5
• Modeling Strategy	10
• Learn Operational Aspects	10
• Development and Input of Time Series	30
• Parameter Development	15
• Calibration and Verification	30

This table is intended as a guide; the relative effort for the various steps of an HSPF application will differ from study to study. For example, application to an area which has been modeled previously using HSPF will require less effort for parameter development and calibration due to knowledge of watershed characteristics. Also, this distribution may vary considerably depending on the familiarity of the user with HSPF and experience in its use.

In addition to the division of total effort into the separate tasks of an application study, the relative timing for the start and completion of each task should also be considered at the beginning of the study. Inevitably,

Table 2.1 HSPF Release 7.0 Run Costs

Computer: IBM 3081 at Stanford University - Center for Information Technology
CPU Rate: $23.10/cpu minute (night/weekend)
Disk I/O Rate: $0.025/1000 (night/weekend)

RUN DESCRIPTION	EXECUTION TIME		DISK I/O		PRINT	TOTAL RUN COST
	cpu min/yr	$/yr	No./yr	$/yr	COST	$/yr
1. NEWTSS Run - create a new TSS file	0.	0.	121	0.10	0.69	0.79
2. TSSM and COPY Run - create 4 data labels in the TSS and transfer 4 time series (3 daily; 1 hourly) into the datasets. Display the time series.	0.06	1.39	2384	1.97	2.54	5.90
3. PERLND Run - 1 land segment (PWATER), 2 displays, 1 plot. INDELT = 1 hour.	0.10	2.31	1384	1.14	3.12	6.57
4. PERLND Run - 3 land segments (SNOW, PWATER), 4 displays, 1 plot, 2 duration analyses. INDELT = 2 hr.	0.35	8.09	4091	3.37	3.14	14.60
5. PERLND Run - 1 land segment (3 BLKS) (SNOW,PWATER,SEDMNT,PSTEMP,MSTLAY, NITR,PHOS,TRAC), 24 displays, 8 plots. INDELT = 1 hour.	1.26	29.11	17644	14.56	7.10	50.77
6. Watershed Run (Pesticide) - 3 land segments (2 with 3 BLKS) (SNOW,PWATER, SEDMNT,MSTLAY,PEST), 8 stream reaches (HYDR,ADCALC,SEDTRN,GQUAL), 36 displays, 10 plots. INDELT = 1 hour.	4.15	95.87 (* 44.51)	45632	37.65	19.24	152.76 (* 101.40)
7. Watershed Run (Agric. nutrients) - 3 land segments (2 with 3 BLKS) (SNOW,PWATER,SEDMNT,PSTEMP,PWTGAS, MSTLAY,NITR,PHOS,TRAC), 8 stream reaches (HYDR,ADCALC,CONS,OXRX, NUTRX), 53 displays, 9 plots. INDELT = 1 hour.	5.18	119.66 (* 55.55)	93223	76.91	30.26	226.83 (* 162.72)
8. Watershed Run (Pesticide) - 9 land segments (SNOW,PWATER,SEDMNT,MSTLAY, PEST), 13 stream reaches (HYDR,ADCALC, SEDTRN,GQUAL), 22 displays, 8 plots. INDELT = 2 hour.	3.44	79.42 (* 36.83)	44798	36.96	20.84	137.22 (* 94.68)
9. Watershed Run (Agric. nutrients) - 9 land segments (SNOW,PWATER,SEDMNT, PSTEMP,PWTGAS,MSTLAY,NITR), 13 stream reaches (HYDR,ADCALC,OXRX,NUTRX), 17 displays, 7 plots. INDELT = 2 hour.	2.59	59.83 (* 27.76)	42425	35.00	20.37	115.20 (* 83.13)

* Run Class = Large ($10.72/cpu min)

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delays in completion of one or more tasks will occur, and the project schedule may be extended; however, many of the tasks involved in a modeling study may overlap; consequently, delays in completion of the overall project can be minimized. Due to differences in goals and modeling strategy, the schedule for one project may be quite different from another. For example, depending on the availability of data, Task # 4, input and management of time series, may begin very early in the schedule, whereas calibration must await some parameter development. By necessity, production runs related to a specific constituent or process cannot start until calibration/verification of that constituent is complete. In order to provide a guide to the user, a representative project schedule based upon the Iowa River and Four Mile Creek studies is presented in Figure 2.1.

In summary, this section is intended to emphasize the importance of considering the specific budgetary and time requirements of an HSPF application during the study definition, and particularly to provide a guide to the user for estimating the resources required and the relative timing of the project tasks. While model applications may differ greatly in scope and purpose, it is hoped that the representative data derived from pilot studies and presented here will be useful in this process.

2.4 Study Definition Process for the Iowa River Study

This discussion illustrates how the guidelines developed in Sections 2.1-2.3 were used to define a realistic scope of work for the Iowa River Study. As noted previously, the Iowa River Study was a demonstration application of HSPF on a large river basin to evaluate the effects of agricultural nonpoint pollution and proposed best management practices (BMPs). Since the study was intended to demonstrate a methodology, its goals were somewhat different than those of most engineering applications in that study results were not intended as a basis for making specific engineering or planning decisions. Nonetheless, modeling results had to be reasonable in order to demonstrate the validity of the model algorithms and the modeling approach. In defining a clear set of goals for the Iowa River Study the following factors were significant:

(1) The primary intent of the study was to extrapolate a methodology developed on nearby Four Mile Creek (52 km2) to the Iowa River Basin (7240 km2) to demonstrate its applicability and functionality on a large river basin. Consequently, considerable

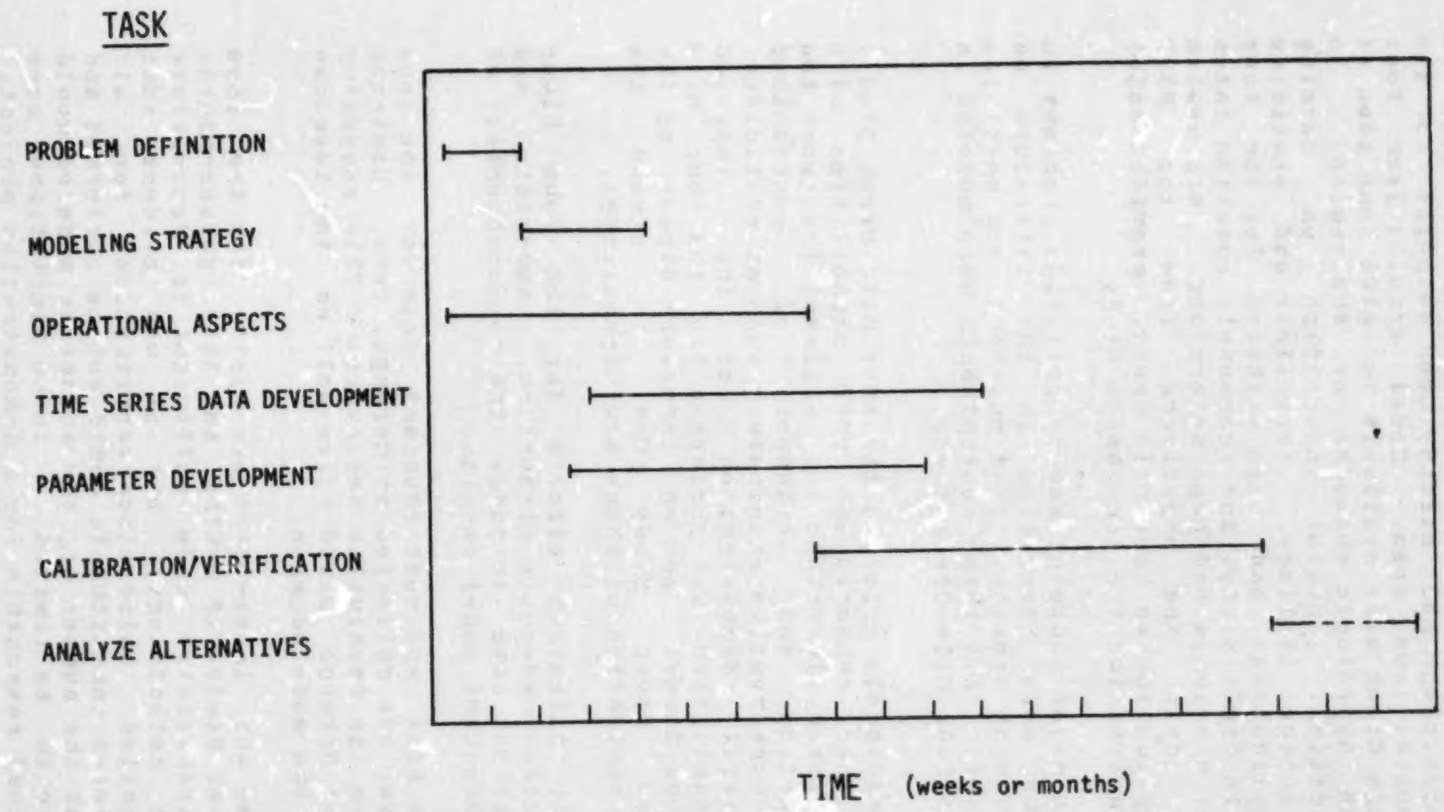

Figure 2.1 Representative HSPF Project Schedule

information on soils, topography, land use, and meteorology had already been gathered for the central Iowa area. Model results from Four Mile Creek were available to give some idea of the hydrologic response of the region. In addition, useful information on farming practices (tillage, fertilizer and pesticide application) had been gathered for the Four Mile Creek Study, and reasonable reaction rates for chemicals had been determined. This wealth of data and experience from the HSPF application on Four Mile Creek, provided major benefits for the Iowa Basin Study.

(2) The major nonpoint source pollution problems in Iowa were identified in the literature as sediment erosion, and nutrient and pesticide runoff. All three contaminants were modeled in the Four Mile Creek Study.

(3) Immediately prior to the Four Mile Creek Study, we had enhanced the HSPF capabilities with improved algorithms for sediment transport and reaction and transport of generalized nonconservative chemicals, such as pesticides. Initial demonstration of the improved capabilities was performed in the Four Mile Creek Study, and an important aspect of the Iowa River Study was to expand the demonstration of these new capabilities.

(4) Data gathering efforts for the Iowa River yielded adequate streamflow, sediment, and nutrient data to judge the reasonableness of subsequent model results.

(5) The best and most abundant data for the Iowa River was collected at Marengo, Iowa, upstream from the Coralville Reservoir. This suggested that Marengo would serve well as the terminus of the modeled area.

(6) Time and level-of-effort limits for the Iowa River Study (8 months and 1400 person-hours, respectively) were sufficient to demonstrate the methodology, but it was evident that detailed calibration/verification for all modeled constituents could not be performed and that the number of BMP scenarios modeled would have to be limited. These limitations were deemed reasonable for a demonstration project.

Based on the above listed considerations, we refined the study goals to include the following points:

(1) The study area was restricted to the watershed above Marengo, Iowa.

(2) The modeling effort was restricted to hydrology, sediment, nutrients, and one pesticide.

(3) Data acquisition was limited to material useful in modeling these four constituents.

(4) The planned calibration/verification effort was limited. The goal of calibration would be a general agreement between simulated and observed values primarily for the flow and sediment; no further refinements would be made

(5) Simulated BMP scenarios would be limited to one or two depending on remaining resources in the later stages of the modeling effort.

The concise scope of work developed above allowed us to design a modeling strategy which would realize study goals in an efficient, cost-effective manner.

2.5 Summary

Depending on project goals and resources, the amount of effort devoted to many aspects of a modeling study can either be reduced or expanded. Areas of the model application which exhibit the most flexibility with respect to required level of effort include the following:

- complexity of land and channel segmentation
- chemical sources and constituents considered in the simulation
- simplified versus detailed simulation algorithms
- level of detail and effort for calibration/verification process procedures
- number and level of detail for analysis of alternate scenarios

All of these topics will be discussed in more detail in subsequent chapters. It is evident from the above list that the relative effort devoted to the various steps of a modeling study can be modified to a certain extent at any point in the project. Generally speaking, however, a modeling study is most likely to be successful if major changes are not made to the modeling strategy and scope of work in the later stages of the project unless they are absolutely necessary. Careful definition of study goals, followed by development of an appropriate and comprehensive modeling strategy is needed for efficient performance of all steps of the model application.

SECTION 3

DEVELOPMENT OF A MODELING STRATEGY

The second step in applying HSPF to a study area is the development of a simulation plan or strategy, based on characterization of the area with regard to meteorologic conditions (and spatial variability), soils characteristics, topography, land use, pollutant sources, available historic data, etc. Meteorologic data must be identified which are representative of the various segments of land to be modeled. A basin segmentation scheme must be developed which defines areas of homogeneous hydrologic response based on soils characteristics and land use, as well as weather conditions. A representative channel system including both hydraulic and geometric characteristics is needed. Streamflow and water quality data which can be used to calibrate the model must be examined, and a modeling strategy which makes full use of available data must be devised.

The relative importance of various pollutant sources must be ascertained. For those pollutant sources which are deemed significant to model results, a general characterization of pollutant behavior (accumulation, removal, influence by, and response to land use activities) must be defined. The purpose of this section is to outline the general characterization process. Frequent references to the Iowa River Study are made to illustrate the process and decisions involved in developing a modeling strategy. Important considerations in developing modeling strategies for other applications are noted. The discussion is divided into five subsections:

- selection of constituents and sources to be modeled
- preliminary segmentation of land area based on weather data
- final segmentation of the land area
- segmentation and characterizaton of channel and contributing areas

- characterization of special actions or events

3.1 Selection of Constituents and Sources to be Modeled

An important first step in developing the modeling strategy for a study is to decide which constituents will be modeled. Concurrently, the user must assess which sources of constituents (e.g., point loadings, nonpoint loadings, chemical transformations, instream sources) are significant to the water and chemical mass balances for the study area, and how to characterize these sources for modeling purposes. This section provides the first-time model user with general guidelines for accomplishing these tasks.

Selection of Constituents. As discussed in Section 2.1, the choice of which constituents will be modeled is strongly influenced by study goals and resources. All constituents modeled by HSPF are key indicators of one or more different aspects of water quality. For example dissolved oxygen, water temperature, and sediment are key constituents which must be considered if maintaining a suitable environment for fish is a study concern. On the other hand, nitrates, phosphates, and pesticides are critical constituents when evaluating the impacts of nonpoint source pollution from agriculture. In every case, study goals will necessitate the modeling of certain constituents, while others will not be nearly as critical to answering study questions. Generally speaking, in order to conserve project resources, one should avoid modeling constituents which are peripheral to the main concerns of the study.

The resources available to perform a study are an important factor in the selection process. By consulting others involved in the application of HSPF and by reviewing the general cost and effort guidelines for using the model (Section 2.3), one should assess whether or not a reasonable list of constituents has been selected for simulation. At the same time the user must consider whether or not existing data is adequate to characterize important constituent sources and processes and to allow reasonable calibration and verification of the model. While data deficiencies do not preclude the modeling of a constituent, one must give careful consideration to validity of results which are not supported by good data.

An additional factor which must be considered if constituents other than water are to be modeled is the hierarchical nature of biochemical interactions. Due to the interrelationships which exist between various constituents and processes, the simulation of some constituents cannot be carried out independently of others. In all three modules (PERLND, IMPLND, RCHRES) water must be simulated (or available from a previous run or observed data) if any other constituent is to be simulated. While modeling conventions and simplifications in the land surface modules (i.e. PERLND, IMPLND) allow the independent simulation of specific constituents, a good deal of interdependency is exhibited by the constituents and instream processes modeled in RCHRES. For example, while water temperature is not affected by any other simulated constituent, dissolved oxygen concentrations are dependent on water temperature and cannot be simulated independently. Most of the constituents which are modeled in RCHRES are in some way related to other constituents. Table 3.1 shows the hierarchy of dependency for RCHRES constituents.

For example, if phytoplankton growth dynamics were the subject of study, then water temperature, dissolved oxygen, biochemical oxygen demand, nutrients, and zooplankton (i.e., groups 4, 7, 8, and 9) must be modeled in order to fully model phytoplankton population fluctuations. However, if a chemically conservative substance such as total dissolved solids were the only constituent of interest, simulation of additional constituents is not necessary.

Each constituent within each group does not need to be simulated. There are allowable variations and minimum criteria established for each group. The functional description portions of the User's Manual (Part E, Sections 4.2(1)-4.2(3)) describe the allowable combinations of constituents within each group and should be reviewed before the final selection of constituents is made.

While the interdependencies discussed above usually require that additional constituents be simulated, sometimes these requirements may be satisfied by a user-input time series. When available, this option may be preferable in situations where the required data is easy to estimate or will have minimal effect on the primary constituents to be simulated. For example, if the temperature dependence of instream chemical processes is low, the use of an approximate water temperature time series is appropriate. Or, if it is known that suspended sediment concentrations are generally low, user-estimated time series for use in the instream photolysis and photosynthesis algorithms are preferable to the added cost and data requirements of performing a detailed sediment simulation. The user should note, however, that this option does not eliminate the interdependencies specifically within section RQUAL; simulation of plankton, for example, always requires simulation of dissolved oxygen, BOD, and instream nutrient processes.

TABLE 3.1 CONSTITUENT HIERARCHY IN HSPF FOR INSTREAM MODELING

GROUP *	CONSTITUENTS	GROUP DEPENDENCY
1	hydraulics (water)	none
3	conservatives	1
4	water temperature	1
5	inorganic sediment	1,4 **
6	general quality constituent	1,4 ***
7	dissolved oxygen, BOD	1,4
8	inorganic N and P ammonia nitrate nitrite phosphate	1,4,7
9	plankton phytoplankton zooplankton benthic algae organic N,P,C	1,4,7,8
10	pH, inorganic carbon pH carbon dioxide total inorganic carbon alkalinity	1,3,4,7,8,9

* group numbers correspond to module section numbers used in the Activity Block of RCHRES

** water temperature required if Colby method used for simulating sand; user may either simulate water temperature or provide an input time series

*** simulation may be dependent on additional constituents depending on the algorithm options which are used; refer to functional descriptions of module section GQUAL in the User's Manual.

Based on the above discussion a reasonable procedure for selecting the constituents to be modeled is outlined below:

1. Review project goals and the questions which must be answered by modeling.

2. Establish which constituents modeled by HSPF are the best indicators for addressing these questions, and make a preliminary list of these constituents.

3. Review project resources to make sure that sufficient time, money, and data are available to support the simulation of the constituents contained on this list. If not, review step #2 and reduce the list to an appropriate length.

4. If instream simulation will be included in the modeling effort, refine the preliminary list to include constituents which must be modeled or input due to constituent interdependencies. Re-evaluate available project resources.

Determination of Constituent Sources to be Modeled. There are six possible sources of water and/or other constituents which are modeled by HSPF:

- initial storages
- nonpoint loadings (including atmospheric deposition)
- point loadings
- chemical transformations
- releases from the channel bottom
- atmospheric gas invasion

Of these, the first three listed are the only sources of water, while all six are potential sources of other constituents. Nonpoint source loadings are usually simulated with the PERLND and IMPLND sections while point source contributions are specified as a input time series defined by the user. The chemical transformation, benthal release, and gas invasion algorithms in HSPF are specific to certain constituents; consequently only those chemicals listed below can be introduced by these processes:

Chemical Transformations	Benthal Releases	Gas Invasion
BOD	BOD	dissolved oxygen
inorganic N (ammonia, nitrite, nitrate)	ammonia or nitrate	carbon dioxide
organic N	orthophoshorus	
orthophosphorus	carbon dioxide	
organic P		
phytoplankton		
zooplankton		
benthic algae		
carbon dioxide		
total inorganic carbon		
organic carbon		
daughter products from degradation of generalized constituents		
plant nitrogen		
plant phosphorus		

Specification of initial storages is required for all constituents to be modeled. Depending on the nature of the study, one or more additional sources will be important to the modeling effort. To a large extent the algorithms which represent chemical transformations are an integral part of the model and will degrade some chemicals and produce others in a manner which is designed to be consistent with the real world based on current knowledge. Thus, of the six potential sources of water and/or constituents, both initial storages for water and chemicals, and chemical transformations will be included in almost every study which is not purely a hydrologic investigation.

The purpose of the remainder of this discussion is to provide guidelines for assessing whether or not each of the other four potential sources of constituents (i.e., nonpoint loadings, point loadings, benthal releases, gas invasion) is significant to the overall water and/or mass balances for the study area, and hence must be represented in the modeling effort.

In making this assessment, one should consider the following:

1. Nonpoint loadings are commonly associated with almost any type of human activity within a watershed. It is unlikely that nonpoint source pollution can be ignored in most comprehensive water quality studies of watersheds.

2. It may be possible to model the land surface of predominantly rural land using only the PERLND

module; generally, both the PERLND and IMPLND modules are required to adequately model urban areas. Before deciding whether to utilize one or both modules the model user should review the differences between the two modules in representing hydrologic and water quality processes which are important to the study area. Whether or not simulation of both pervious and impervious surfaces is necessary is influenced by the constituents which are being simulated, their relative accumulation on the two types of surface, and the relative abundance of each surface type in the watershed.

3. If instream processes are not simulated, initial storages, chemical transformations on the surface and in the soil, and washoff from the land surface are the only chemical sources which can be modeled.

4. Simulation of point sources is required under the following circumstances:

   - if a significant fraction of the water volume for the study area is contributed by point sources, at least on a seasonal basis. (In some urban watersheds, all summer streamflow is from point sources.)
   - if the chemical loadings associated with point sources are a significant source of the constituents being modeled.

   In most areas of the United States, point loadings from industry and municipalities have been inventoried in terms of mean flow and type of effluent, and often some chemical concentration data is available. A simple, first-cut technique of assessing the significance of point sources is to sum the mean flows of all loadings and compare this number to mean streamflow and low flow during the simulation period at various points with good records in the study area. Comparison of these values will give a reasonable indication of the dilution capacity of the stream.

   At the same time it is often useful to develop an estimate of mass contributions of selected constituents from the point sources. This can be done by developing mean chemical concentration estimates for each source, then multiplying mean concentrations by mean flow to derive mass contributions for each point load, and finally summing mass contributions from all point sources. If instream chemical concentrations are available near the streamflow gage, a rough estimate can also be made of total mass loadings to the stream from all sources. By comparing these estimates, the modeler can make an intelligent decision on whether point sources should be modeled.

5. Simulation of benthal releases is limited to inorganic nitrogen, orthophosphorus, carbon dioxide, and biochemical oxygen demand (BOD). Generally speaking, benthal releases are only significant in slow-moving bodies of water which are subjected to heavy loadings of nutrients and/or organic material. Settling of dead organic material and subsequent decomposition is paralleled by the release of inorganic materials and soluble BOD. Under some conditions, particularly periods of scour from high flows, benthal releases can be an important source of these constituents.

6. Simulation of atmospheric gas invasion is only necessary if instream processes are simulated and either dissolved oxygen or carbon dioxide are to be modeled. If so, it is useful to use sections PWTGAS and IWTGAS to estimate the resulting concentrations of gases in the runoff entering the channel system from pervious and impervious areas, respectively. In addition, gas invasion at the surface of the channel waters must be simulated using the RQUAL Section.

Characterization of Sources. Once the modeler has decided which sources of water will be modeled, the following suggestions should prove useful in characterizing these sources:

1. Generally, assigning values to initial storages is not a major problem. However, one must be careful not to assign initial values which exert an unreasonable effect on simulation results. For example, if an unrealistically large initial value is specified for the land surface storage of a particular chemical, it is

possible that simulated washoff for a significant portion of the simulation period will be biased. The modeler should always examine the simulation results in the first time intervals of initial computer runs to assess whether problems of this nature are occurring.

2. Parameter requirements for characterizing nonpoint source chemical loadings may be found in the User's Control Input (Part F, Sections 4.4(1-3)). While considerable data are available which allow general characterization of chemical accumulation and removal for different types of land and different land uses, the modeler will most often be forced to make an educated guess at characterizing nonpoint sources in the study area. Examination of preliminary simulation results may convince the modeler to adjust certain aspects of the characterization. Given the uncertainties involved in characterizing nonpoint sources in most watersheds, the accumulation/removal parameters are often treated as calibration parameters.

3. In most cases, characterization of point sources is relatively straightforward. For each point source, a time series of values is required for flow and for all constituents which are being simulated. The time series of data must span the entire period of simulation. Quite often a constant value for flow and constant values for chemical concentrations are used in the absence of better data; daily, monthly, or seasonal values are preferred if data is available. General guidelines are available for characterizing municipal and many industrial effluents (Metcalf and Eddy, 1972; Dyer 1971). Be aware that if concentration values for a particular constituent are omitted for a point source, HSPF will assume a zero concentration for the volume of water introduced into the reach by the point source.

4. The user has a good deal of control over whether or not particular chemical transformations or benthal releases are simulated. If they are, rate coefficients allow further control on the impact of these processes on simulation results.

__Data Input Procedures for Characterization of Sources__. Because of the large number of constituents and processes which can be modeled by HSPF, it is not practical to give detailed instructions on how to provide the model with the necessary input to properly characterize each possible source of each possible constituent. Nonetheless, the following general statements may be helpful:

1. Initial storages must be specified in the User's Control Input for each constituent modeled by PERLND, IMPLND, or RCHRES. The input tables used to specify initial storages are usually located after the parameter tables specified for each module section (see Part F of User's Manual) and usually have a table name containing a phrase such as "STOR", "INIT", or "STATE".

2. The numerous parameters which control the quantity of nonpoint source loadings simulated by HSPF are contained in the UCI tables for modules PERLND and IMPLND.

3. Point loadings data are input to HSPF by using the External Sources and Network Blocks. Guidance is provided in Section 4.6 of Part F of the User's Manual.

4. As already indicated, chemical transformations are a source of certain constituents in all three application modules. Numerous tables in the UCI are used to characterize the transformations which are modeled.

5. Three tables in the RCHRES UCI are used to characterize benthal releases. Table-types OX-BENPARM, NUT-BENPARM, and PH-PARM2 are used to provide the necessary input for simulating bottom releases of BOD, nutrients, and carbon-dioxide respectively.

6. In HSPF, gas (dissolved oxygen and carbon-dioxide) concentrations in runoff from both pervious and impervious surfaces are assumed to be at saturation; hence user input is not required. However, for instream gas invasion a limited amount of information must be supplied by the user in Table-types OX-CFOREA (for oxygen) and PH-PARM2 (for carbon-dioxide).

This discussion on characterizing constituent sources is intended to provide the user with a preliminary understanding for the procedures and effort which will be necessary to provide the model with the information it needs to simulate the constituents and sources which have been selected. Additional details for performing the characterization are provided in the discussion of parameter development contained in Section 6.

3.2 Preliminary Segmentation of Land Area Based on Weather Data

This discussion focuses on the development of an appropriate representation of the meteorologic conditions for an entire study area based on site-specific weather data from stations in and near the study area. Topics discussed include weather data needs for hydrologic and water quality simulation, importance of different weather data types to simulation results, interpretation and evaluation of available data, and criteria for selection of the best station records and representation scheme for the study area.

Time series weather data are critical inputs to HSPF for both hydrologic and water quality simulation. All hydrologic simulations of runoff require precipitation and potential evapotranspiration data. Hydrologic studies which simulate snowmelt and water quality studies which simulate water temperature require additional time series data for air temperature, wind speed, solar radiation, and dewpoint temperature. Plankton simulation requires solar radiation data. Depending on the simulation options selected, time series data for wind speed and cloud cover may be needed for simulation of a generalized quality constituent. Wind speed may be required for simulation of dissolved oxygen.

Table 3.2 summarizes the meteorological data required for simulating various processes in HSPF. Further details on time series requirements can be found in Section 4.7 (Time Series Catalog) of the User's Manual.

A necessary task in the HSPF modeling effort is division of the study area into land segments such that each segment can be assumed to produce a homogeneous hydrologic and water quality response. To determine whether meteorologic variations should be accounted for in selecting segments, two factors must be considered. First, the degree of spatial variability exhibited by the data type must be examined. For instance, data suggest that in the Iowa River Basin mean annual air temperature has a much more significant variability across the watershed than does wind speed.

Table 3.2 Meteorological Time Series Data Requirements for HSPF

	ACTIVE MODULE SECTIONS										
	PERLND						RCHRES				
METEOROLOGIC DATA	TEMP	SNOW	PWATER	SEDMNT	PSTEMP	SOIL/AG CHEM	HYDR	HTRCH	GQUAL	OXRX	PLANK
Precipitation	*	*	*	*		* 1	+	+			
Pot. Evapotranspiration			*	* 1		* 1	+				
Air temperature	*	*			*	* 2		*			
Wind movement		*						*	* 3	* 5	
Solar radiation		*						*			*
Dewpoint temperature		*						*			
Cloud cover								*	* 4		

Notes:
* required time series
+ optional time series
1 required for section PWATER
2 required for section PSTEMP
3 required if volatilization from a lake is simulated
4 required if photolysis is simulated
5 required if RCHRES is a lake

Second, the impact of the data type on simulation results must be considered. Some data types such as precipitation and evapotranspiration are direct determinants of water availability while other data types only affect streamflow timing by altering the rate of spring snowmelt. Consequently, if significant variability does exist over the watershed for a critical data type such as precipitation or evapotranspiration, the use of multiple weather station records is warranted. Simulation results can be further improved in those cases where multiple records for the other meteorological data types are readily available.

It should be noted, however, that there is a limit to the amount of segmentation which should be performed based solely on meteorologic considerations; additional segmentation of the study area, as described in Section 3.3, will be necessary to represent differences in soil characteristics and land use. Thus, if three segments are defined based on meteorologic variability and three land uses are to be simulated, the total number of land segments which must be simulated is nine multiplicative. Major differences in soils characteristics could require an even greater division of segments and the computer costs for simulating additional segments are significant (Section 2.3).

Experience has shown that effective meteorologic representation of most watersheds greater than approximately 100 square kilometers requires at least three different rainfall records, perhaps more if rainfall patterns are highly variable. For watersheds smaller than 100 square kilometers one rainfall record may be adequate if rainfall is reasonably uniform and study goals do not require maximum accuracy. Generally speaking, an effective procedure is to segment the study area based on three or four sets of data which include records of somewhat low, average, and somewhat high rainfall and evapotranspiration. Specific conditions and/or project objectives may require more detailed representation.

If a range of values for critical weather data is represented in the records from the different stations, the model user can maintain a degree of flexibility in simulation results by adjusting the amount of study area land which is represented by each of the sets of meteorologic data. This procedure was used in the Four Mile Creek Study, and is described in its final report (Donigian et al., 1983b).

A number of factors are involved in selecting the most appropriate weather data for a study area. Among these are:

- long term behavior of study area weather
- differences between long term area behavior and long term record behavior for specific stations
- spatial variability in study area weather exhibited in both short and long term records
- accuracy and completeness of station records

How these factors affect the selection of weather data for a modeling effort is best shown by example. Consequently, the detailed description of the weather data selection process for the Iowa River Basin Study has been extracted and included below. Each data type is considered separately since the selection procedure varied depending on availability of data, spatial variability of the data type, and the impact of the data type on simulation results.

General Availability of Data. There are 18 NOAA weather stations in or near the 7,240 square kilometer Iowa River Basin above Marengo. The location of each station in relation to the watershed boundary is shown in Figure 3.1. Additional meteorologic data were available from the Iowa State University and Four Mile Creek Weather Station near Traer. Precipitation, maximum and minimum air temperatures, humidity, pan evaporation, solar and net radiation have been recorded at this station. However, the station was closed during winter months and has experienced numerous equipment failures; consequently, records are incomplete.

Precipitation. Mean annual precipitaton for the basin varies from 762 millimeters in the north to 838 millimeters in the southeast (Figure 3.2). Given the primary importance of precipitation data to the simulated water balance, three records were used. Both long term averages and records for the selected simulation period (1974-1978) suggest that the Traer precipitation is representative of the southeastern third of the basin, which receives 813 to 838 mm of yearly rainfall.

The central section of the basin has a long term average annual precipitation in the range of 787 to 813 mm, and can be well represented by the Iowa Falls record. The Iowa Falls station recorded an average of 757 mm of annual rainfall during the 1974-1978 simulation period, somewhat lower than the long term average. (Lower than average rainfall was recorded at all stations within the basin for the 1974-1978 period.) The Iowa Falls record was generally good. Records were missing for 17 days, and were filled in using data from the Ames station.

The northern section of the basin is characterized by 762 to 787 mm of average rainfall. Inspection of the records for the two best candidate stations, Forest City and Sheffield, showed large periods of missing data for both. Sheffield was selected as the base record and was updated using Forest City data when available (43 days). Remaining gaps (53 days) were filled using Iowa Falls data.

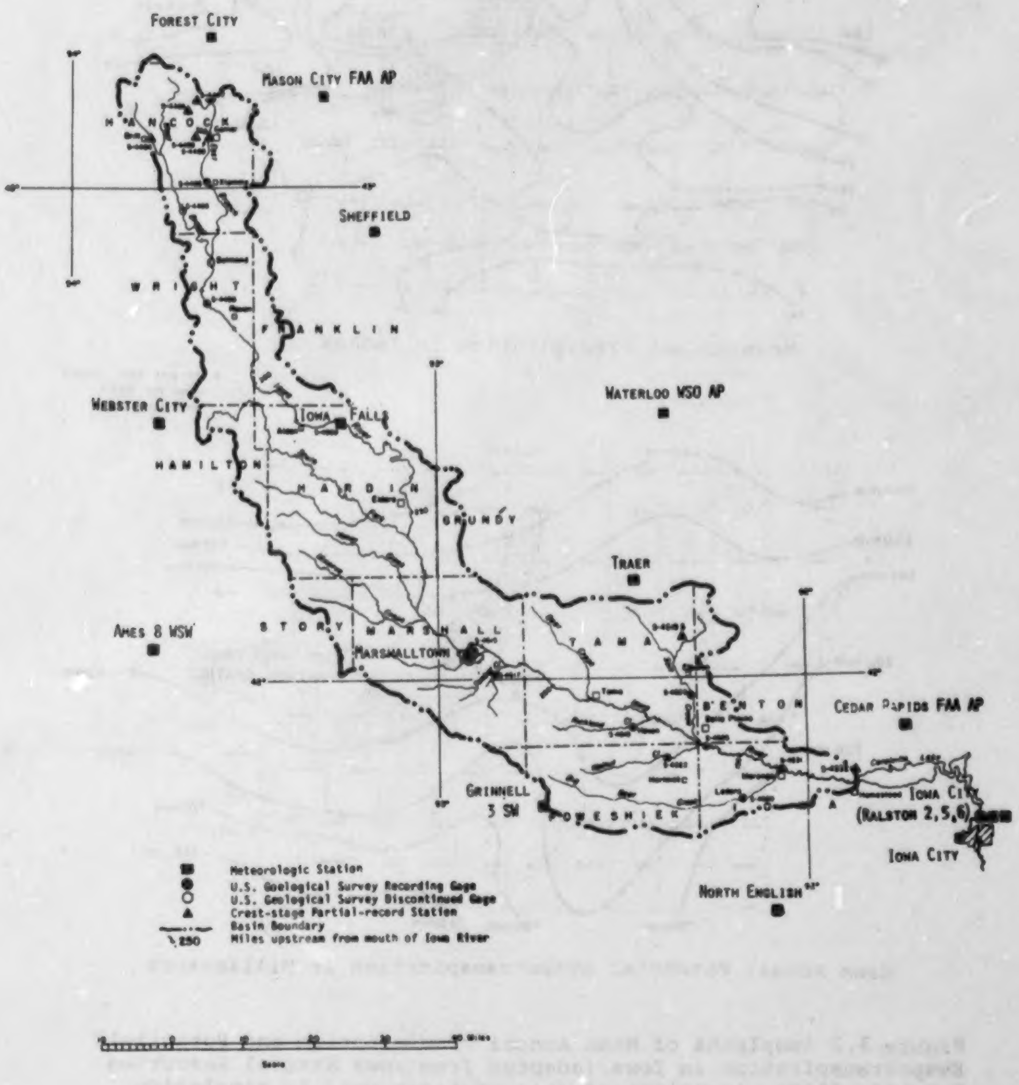
FOREST CITY
MASON CITY FAA AP
HANCOCK
SHEFFIELD
WRIGHT
FRANKLIN
WEBSTER CITY
IOWA FALLS
WATERLOO WSO AP
HAMILTON
HARDIN
GRUNDY
TRAER
AMES 8 WSW
STORY
MARSHALL
MARSHALLTOWN
TAMA
BENTON
CEDAR RAPIDS FAA AP
GRINNELL 3 SW
POWESHIEK
IOWA CITY (RALSTON 2,5,6)
IOWA CITY
NORTH ENGLISH
■ Meteorologic Station
● U.S. Geological Survey Recording Gage
○ U.S. Geological Survey Discontinued Gage
▲ Crest-stage Partial-record Station
Basin Boundary
250 Miles upstream from mouth of Iowa River
0
10
20
30
40 Miles

Figure 3.1 Meteorologic and U.S.G.S. Gaging Stations in and near the Iowa River Basin.

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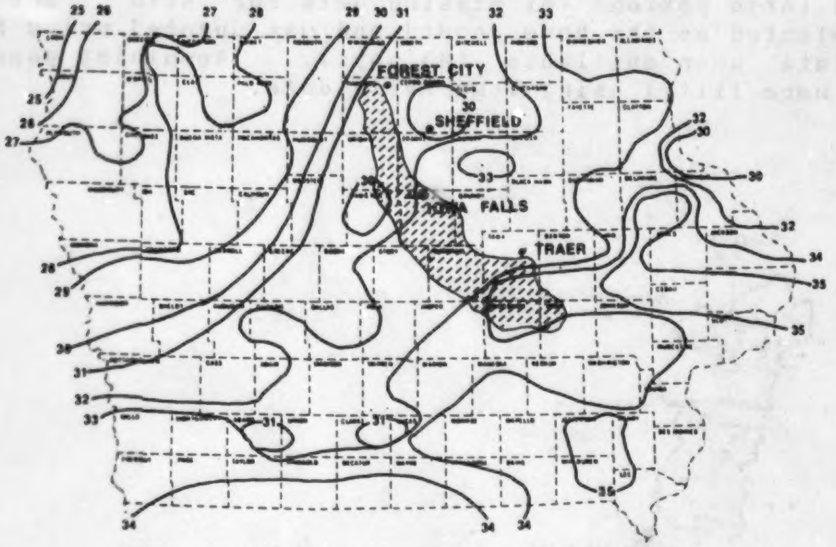
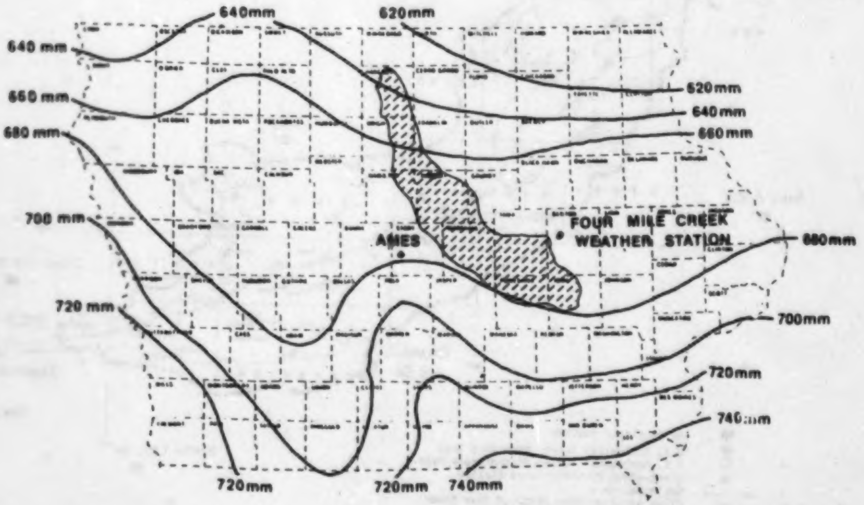

25
26
27
28
29
30
31
32
33
34
35
FOREST CITY
SHEFFIELD
IOWA FALLS
TRAER

Mean Annual Precipitation in Inches

• denotes data station used for HSPF simulation effort


640mm
620mm
640 mm
660 mm
680 mm
700 mm
720 mm
620mm
640mm
660mm
680mm
700mm
720mm
740mm
720mm
720mm
740mm
AMES
FOUR MILE CREEK
WEATHER STATION

Mean Annual Potential Evapotranspiration in Millimeters

Figure 3.2 Isopleths of Mean Annual Precipitation and Potential Evapotranspiration in Iowa (adapted from Iowa Natural Resources Council, 1978). Locations of data stations used in simulation are noted on maps.

Potential Evapotranspiration (PET). Mean annual PET for the Iowa River Basin varies from 635 mm in the north to 686 mm in the far south (Figure 3.2). Three sets of PET data are available: Ames, Iowa City, and Four Mile Creek Weather Station. The record used for simulation was a composite of Four Mile Creek Weather Station and Ames data. All data prior to July 1976 is from Ames, while that occurring after July 1976 is primarily Four Mile Creek Weather Station data, with missing values obtained from Ames. The ten year (1969-1978) average annual PET for the combined record is 630 mm; this suggests that the record may be a little low for the southern portion of the basin. However, since the record was used successfully for the Four Mile Creek simulation, it was considered adequate to represent the PET for the overall basin.

Air Temperature. Long term records indicate a strong relationship between station latitude and mean annual air temperature (Figure 3.3). Short term records show more variability, but indicate that the 1974-1978 period was cooler than typical. Given the fact that the stations which are selected are used to represent temperature characteristics over large areas of land, stations which exhibit reasonably close agreement between long and short term records are more likely to be representative of the large regions. Selection criteria for air temperature records are listed below in order of importance:

1. Three stations were needed, one to represent each of the three basin sections delineated for the precipitation records.
2. Close agreement between long and short term records was desirable.
3. The short term record should be somewhat cooler than long term record.
4. Stations should be within the watershed boundaries.

Based on these criteria the three air temperature records chosen for the Iowa River Basin simulation were Iowa Falls, Marshalltown, and Cedar Rapids.

Iowa Falls - The station is located inside the watershed, and its short term and long term records are similar. The mean annual temperature is about 8.6 degrees C, and the record was used to represent the upper third of the basin.

Marshalltown - The station is located inside the watershed, and its short and long term records are similar, with the short term record somewhat cooler. The mean anual temperature is approximately 9.2 degrees C, and the record was used to represent the middle portion of the basin.

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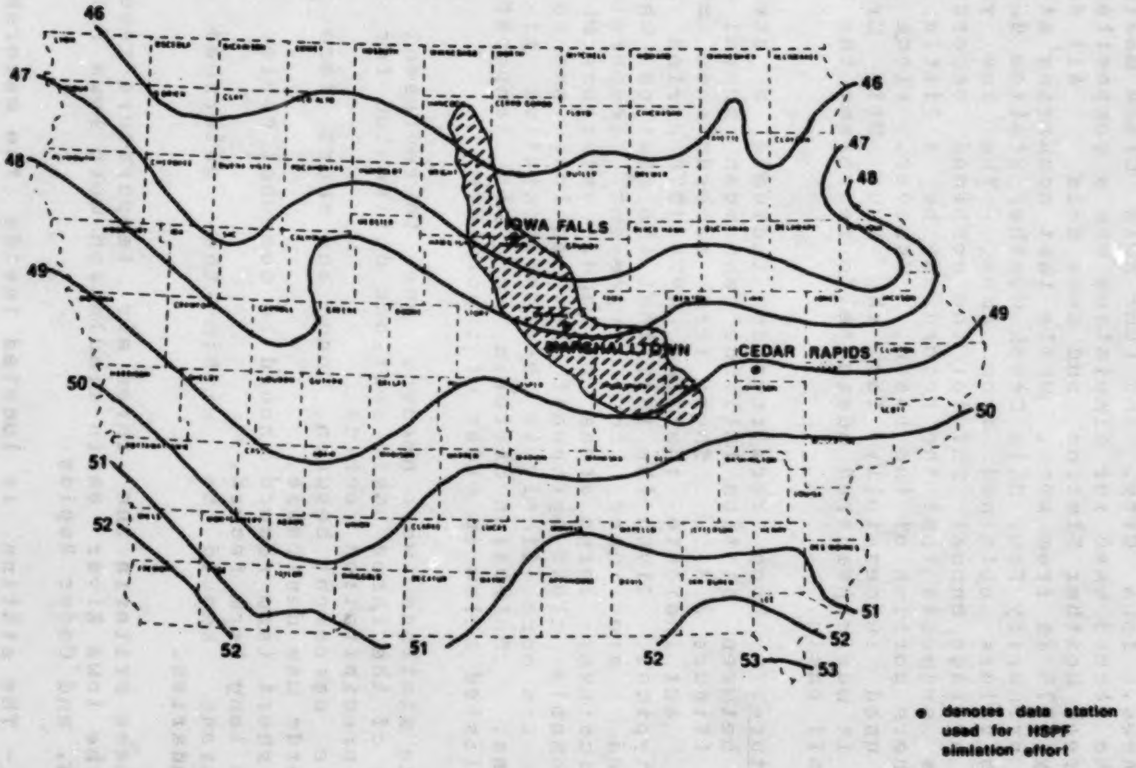
46
47
48
49
50
51
52
53
IOWA FALLS
MARSHALLTOWN
CEDAR RAPIDS
● denotes data station used for HSPF simlation effort

Figure 3.3 Isopleth of Mean Annual Temperature (°F) in Iowa (adapted from Iowa Natural Resources Council, 1978). Locations of data stations used in simulation are noted on map.

Cedar Rapids - The mean annual temperature of this station is approximately 9.7 degrees C, which makes the station representative of the lower porton of the basin. The short term mean annual temperature is similar but somewhat cooler than the long term record. The station is located outside of the watershed, but appears to better represent the lower third of the basin than any other station.

The quality of all three records was excellent, with a total of seven records missing for the entire simulation period. These records were filled in using data from nearby stations. All records consisted of maximum and minimum air temperatures. These data were distributed to hourly values for use by HSPF.

Wind Speed. Wind data for the state of Iowa do not vary greatly from station to station. Consequently, the wind data from Four Mile Creek Weather Station (corrected using Waterloo data), which were used for the Four Mile Creek simulation, were examined to determine whether the record would adequately represent the entire Iowa River Basin. Analysis showed that the mean average hourly wind speed over any given month of the ten year Four Mile Creek record did not vary from the long term composite Iowa value for the same month by more than 1.6 km/hr. Comparison of mean annual wind speeds showed a composite statewide value of 12.2 km/hr at 0.3 meters above the land surface versus a value of 12.1 km/hr for the Four Mile Creek data. The Four Mile Creek record had considerable gaps in it and was updated for the Four Mile Creek simulation using Waterloo data. This composite record was used for the entire Iowa River Basin.

Solar Radiation. Comparison was made between the Four Mile Creek Weather Station solar radiation data and that at Ames (approximately 80 kilometers away) to assess the variability of radiation within the basin area. For the 18-month period from July 1976 to December 1977 the records differed by 3%, with a maximum monthly variation of 20% for the month of March 1977. Given the limited variability in these two records, the radiation record which was used for the Four Mile Creek simulation was used to represent the entire Iowa River Basin. This record is a composite of Four Mile Creek Weather Station and Ames data. All data prior to July 1976 is from Ames, while that occurring after July 1976 is primarily Four Mile Creek Weather Station data, with missing values obtained from Ames.

Dewpoint Temperature. Previous studies have shown similarity between average daily dewpoint temperature and minimum daily temperature. Comparison of these two values on a daily basis for a 60-day record at Waterloo verified this relationship. Given the fact that only one dewpoint record (Mason City) is available near the study basin, it was decided that the best representation of dewpoint temperature could be obtained by using daily minimum temperature records for the three basin segments (Iowa Falls, Marshalltown, Cedar Rapids).

Based on the above analysis of available weather data from stations in or near the Iowa River Basin, it was deemed necessary to divide the study area into three meteorologic segments in order to adequately represent observed variability in precipitaion and air temperature. While the boundaries between the three segments were still reasonably uncertain at this point in the segmentation process, it was useful to summarize the planned use of meteorologic data in Table 3.3 for use in developing input sequences once the segment boundaries were finalized.

TABLE 3.3 SUMMARY OF METEOROLOGIC DATA USED TO REPRESENT THE THREE SEGMENT GROUPS OF THE IOWA RIVER BASIN

	source of meteorologic record used to represent each segment *		
data type	segment #1	segment #2	segment #3
precipitation	Sheffield/ Forest City	Iowa Falls	Traer
potential evapotranspiration	FMC**/ Ames	FMC/ Ames	FMC/ Ames
air temperature	Iowa Falls	Marshalltown	Cedar Rapids
wind speed	FMC/ Waterloo	FMC/ Waterloo	FMC/ Waterloo
solar radiation	FMC/ Ames	FMC/ Ames	FMC/ Ames
dewpoint temperature	Iowa Falls (min. daily temp.)	Marshalltown (min. daily temp.)	Cedar Rapids (min. daily temp)

* The second station noted in some entries was used to fill in missing data records in the primary station.

**FMC = Four Mile Creek Weather Station

It is useful to emphasize several aspects of the data selection process used in the Iowa River Study. The following suggestions are general in nature and can be applied to the data evaluation and selection process for any HSPF modeling study.

(1) Locate all meteorologic stations in and near the study area on one map.

(2) Locate long term weather behavior data for the study area in the form of isopleth maps such as Figures 3.2 and 3.3. Use these maps to assess the need for meteorologic segmentation.

(3) For each type of weather data tabulate the length of record and mean annual value (long term record) for each station based on NOAA data summaries.

(4) Locate stations and mean station values on isopleth maps. Use this information to determine which stations are most representative of particular portions of the study area.

(5) Based on available weather data and an assessment of the availability of streamflow and water quality data for calibration and verification of the model, select the period of time which will be simulated.

(6) For each type of weather data and for each station tabulate the mean value for each year of the simulaton period and assess the quality of each record in terms of the number of missing values.

(7) Evaluate these mean annual values to identify short term weather trends for the simulation period and possible anomalies in the short term records which could preclude their use as representative data for large areas. For example, 1974 precipitation records at Sheffield, Iowa, included two very intense rainfall periods which appeared to be localized thunderstorms. Use of the Sheffield record to represent the upper third of the Iowa River Basin resulted in gross oversimulation of runoff for 1974.

(8) If snowmelt is to be simulated, compare the timing of spring warming trends in air

temperature data for the various stations to observed increases in streamflow at gaging stations. Both the timing and amount of snowmelt is dependent on air temperature, and hence, a good simulation of streamflow during the spring months depends on the use of appropriate air temperature data.

(9) Select the best weather station to represent each data type for each planned meteorologic segment.

(10) Fill in missing records using data from nearby stations.

The above discussion assumes that there are a number of weather stations in or near the study area. Depending on the size and location of the study area, the model user may have difficulty obtaining even one set of representative data for a particular weather data type. In particular, data for solar radiation, wind speed, and dewpoint temperature are scarce. As can be seen by the discussion of the selection process for these data types in the Iowa River Study, a certain amount of judgement and approximation is necessary in developing the best input for the modeling effort. The substitution of minimum air temperature records for dewpoint temperature records is an example of such an approximation. It is important that careful consideration be given to selection of meteorologic data in order to avoid the necessity of making changes in the data base at a later point when it is discovered that selected data are not appropriate.

3.3 Final Segmentation of the Land Area

The final segmentation scheme for a watershed cannot be performed until soils characteristics and land uses have been considered. Guidelines were presented above for performing preliminary segmentation of a study area based on meteorologic considerations. This section discusses these additional factors which must be considered in order to develop the final segmentation scheme. First, general definitions for segments and segment groups are provided to clarify the purpose and process of segmenting the study area. Following these definitions, the method used to refine segments in the Iowa River Basin Study is described. This example, along with supporting discussions, illustrates how soils characteristics, topography, and boundaries of contributing areas to river reaches are used to delineate segment groups and how land-use data is used to determine the areal breakdown of segment groups into segments.

One of the basic concepts of watershed modeling using a lumped parameter approach (e.g., HSPF and predecessor models) is the division of the watershed into land segments, each with relatively uniform meteorologic, soils, and land-use characteristics. Similarly the channel system is segmented into 'reaches', with each reach demonstrating uniform hydraulic properties. The entire watershed is then represented by specifying the reach network, i.e., the connectivity of the individual reaches, and the area of each land segment that drains into each reach. Each land segment is then modeled to generate runoff and pollutant loads per unit area to the stream channel. Multiplying the unit area runoff and pollutant loads by the area of each land segment tributary to each channel reach determines the runoff and pollutant loads to each reach; performing these calculations for each reach in conjunction with modeling the instream hydraulic and water quality processes results in the simulation of the entire watershed.

Definition of segment and segment group. For the purposes of HSPF, a segment is defined as a parcel of land which exhibits a homogeneous hydrologic and water quality response. Hence, one set of hydrologic and water quality parameters (both calibration and non-calibration parameters) can be used to characterize all of the land considered as one segment. For modeling purposes, it is not necessary that all of the land in a segment be contiguous. The only requirements are that the segment parameters reasonably represent the hydrologic and water quality charateristics of all land considered as part of the segment, and that the total area of each segment contributing runoff and pollutants to each hydraulic reach is known.

The hydrologic response of a parcel of land is a function of meteorologic patterns, soils characteristics, and land uses. In most cases, meteorologic patterns and soils characteristics allow for a preliminary division of a basin into segment groups. A segment group is a parcel of land which is exposed to meteorologic conditions (rainfall, evaporation, etc.) which for modeling purposes are designated by one set of meteorologic time series. In addition, it is assumed that all of the land in the segment group would exhibit a homogenenous hydrologic reponse if there were uniform land use. In order to make this assumption, soils characteristics must be reasonably consistent throughout the segment group area. Segment groups are subsequently divided into segments, with each segment representing a different land use.

The segmentation process is best shown by example. Consequently, a detailed description of the segmentation of the Iowa River Basin has been extracted and included below.

Preliminary segment groups for the Iowa River Basin. Variability in meteorology over the basin indicated that the Iowa River Basin should be divided into three segment groups in order to perform a reasonable hydrologic calibration (Section 3.2). Based on long-term isopleth information on rainfall and air temperature, tentative boundaries for the segment groups were formulated, followed by a slight adjustment of boundaries based on spatial distribution of soils.

Most of the Iowa River Basin is covered with prairie soil formed from glacial drift, an unconsolidated mixture of gravel and partly weathered rock fragments left by glaciers. Underlying the drift, at a considerable depth, are consolidated rocks that outcrop where the river has cut deep into the drift. The study area has three distinct topographical areas. The first area is the upper end of the basin above Alden (Figure 3.4), where topography is gently undulating to nearly level. In this area drainage is poorly developed, and the land is characterized by depressions which collect water and prevent rapid runoff. Soil associations are predominantly Storden, Clarion, and Webster. The second area between Alden and Marshalltown is more hilly terrain, but is still predominantly Clarion and Webster soils. South of Marshalltown the terrain becomes more level, and the glacial drift soils are covered by loess, a silty, wind deposited material. The topography and loess thickness vary in the region, but generally 1.5 to 4.5 meters of gently sloping loess materials are present. This southern area is in the Tama-Muscatine soil association.

The boundary between the Clarion-Webster and the Tama-Muscatine areas was compared to the tentative boundary between the bottom two segment groups, as defined by meteorologic considerations. It was concluded that the soils association boundary would serve equally well as a boundary between the land represented by meteorologic data sets #2 and #3 (Section 3.3). The preliminary boundary between the two northern segment groups was drawn based on long-term precipitation isohyets and the general breakpoint between the northern flat lands and the central hilly region. These preliminary segment group boundaries are delineated in Figure 3.4.

Comparison of preliminary segment group boundaries to boundaries for contributing areas to hydraulic reaches. A good deal of time and effort can be saved by defining segment group boundaries so that they are superimposed on the boundaries between contributing areas to the individual reaches. To determine whether or not boundaries can be superimposed, the model user must first delineate the contributing area boundaries for reaches as outlined in

Section 3.4. For the Iowa River Basin Study, contributing area boundaries as delineated in Figure 3.5 were examined and it was decided that the preliminary segment group boundaries (Figure 3.4) could be shifted and superimposed onto contributing area boundaries as shown on Figure 3.5. Thus, all land contributing runoff to reaches 1-6 was contained in segment group #1; all land contributing runoff to reaches 7-11 was in segment group #2, and runoff to reaches 12 and 13 was wholly contributed by segment group #3.

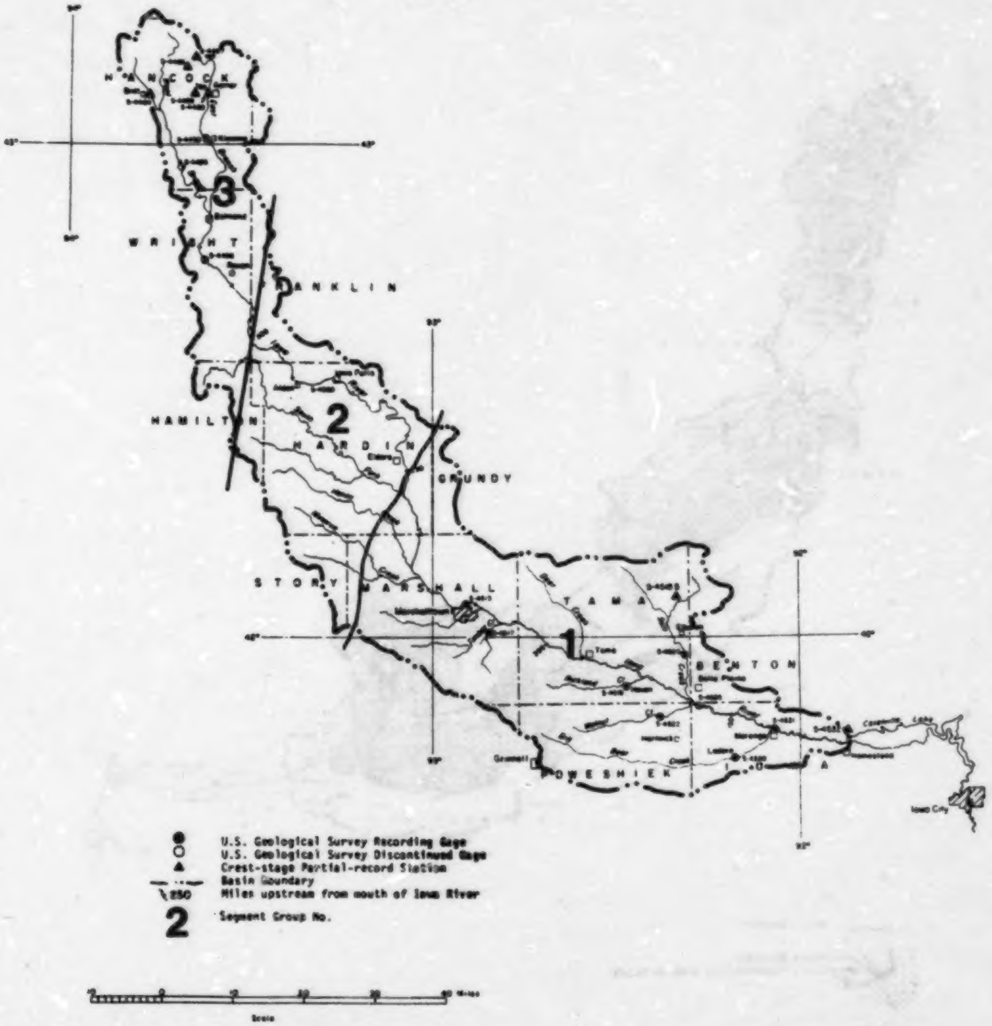
HANCOCK
3
WRIGHT
ANKLIN
HAMILTON
2
HARDIN
GRUNDY
STORY
MARSHALL
TAMA
1
BENTON
POWESHIEK
Iowa City
U.S. Geological Survey Recording Gage
U.S. Geological Survey Discontinued Gage
Crest-stage Partial-record Station
Basin Boundary
250
Miles upstream from mouth of Iowa River
2
Segment Group No.
0
10
20
30
40 Miles
Scale

Figure 3.4 Preliminary Segmentation of the Iowa River Basin to Account for Variability in Meteorologic Patterns and Soils Characteristics.

The three segment groups delineated in Figure 3.6 are the final ones used for the Iowa River Basin Study. The boundaries between segment groups are based on meteorological, edaphic (soils), topographical, and drainage considerations. Evaluation of land-use practices allows the model user to further divide each of the segment groups into segments.

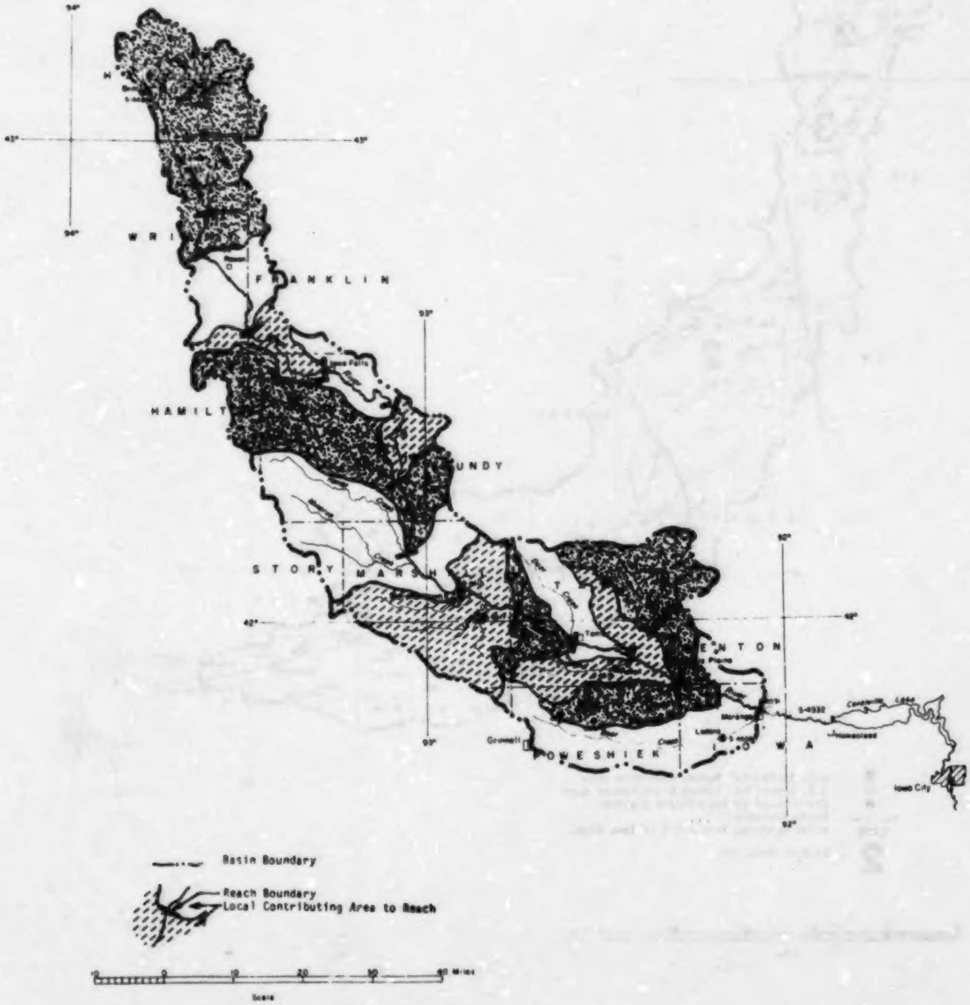
94°
43°
43°
94°
W R I
F R A N K L I N
93°
Iowa Falls
H A M I L T
U N D Y
S T O R Y
M A R S H
92°
42°
42°
E N T O N
93°
Grinnell
O W E S H I E K
I O W A
Marengo
Iowa City
92°
Basin Boundary
Reach Boundary
Local Contributing Area to Reach
10 0 10 20 30 40 Miles
Scale

Figure 3.5 Channel Reaches and Contributing Areas for the Iowa River Basin.

__Land use categories__. The final subdivision of segment groups into pervious land segments (PLSs) and/or impervious land segments (ILSs) is based on land use. Land use types which will have the largest impact on runoff or water quality response in the watershed must be identified. The user must assess whether or not runoff from impervious urban areas is a significant contributor of water and/or pollutants. If so, the amount of impervious area in each segment group must be determined, and pollutant accumulation and removal processes on impervious surfaces must be characterized (Section 3.1).

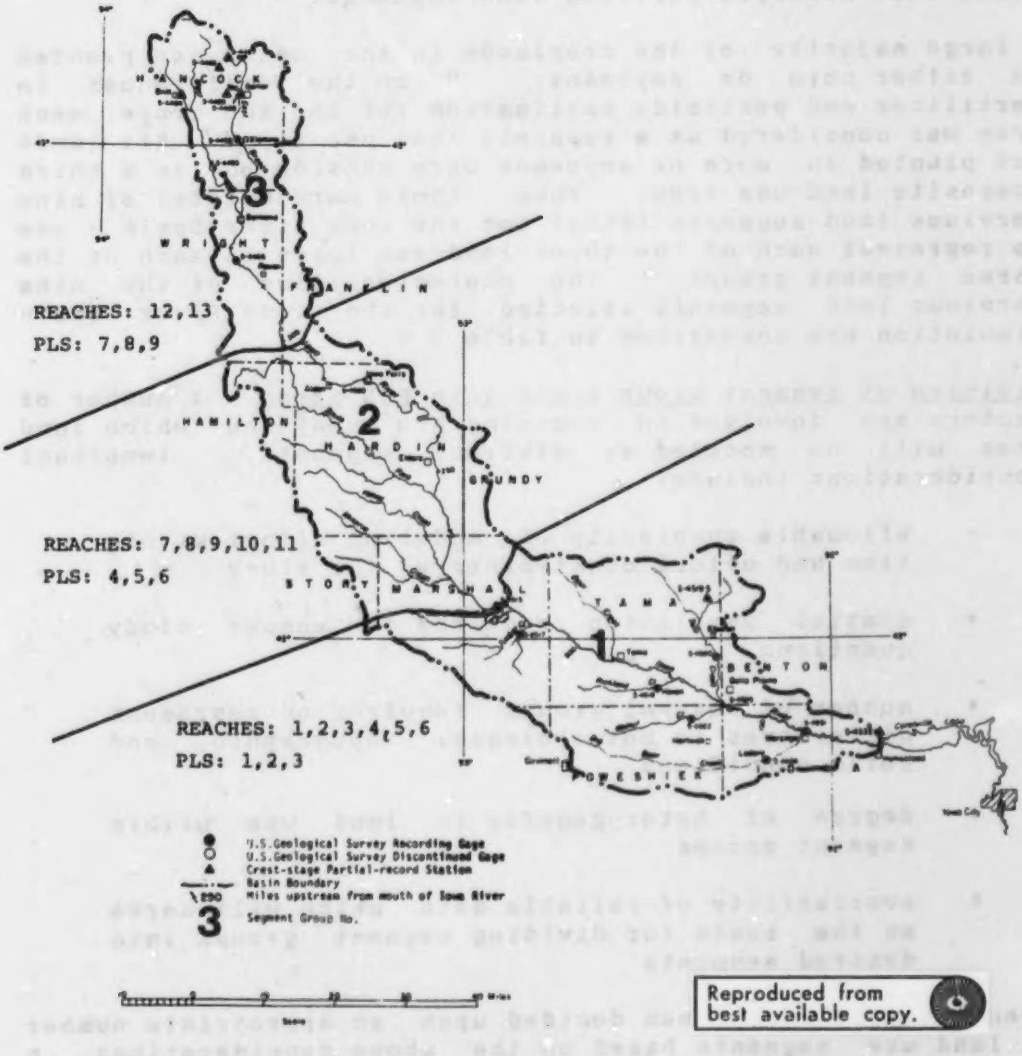
HANCOCK
3
WRIGHT
FRANKLIN
REACHES: 12,13
PLS: 7,8,9
HAMILTON
2
HARDIN
GRUNDY
REACHES: 7,8,9,10,11
PLS: 4,5,6
STORY
MARSHALL
TAMA
1
BENTON
POWESHIEK
REACHES: 1,2,3,4,5,6
PLS: 1,2,3
U.S.Geological Survey Recording Gage
U.S.Geological Survey Discontinued Gage
Crest-stage Partial-record Station
Basin Boundary
Miles upstream from mouth of Iowa River
Segment Group No.
Miles

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Figure 3.6 Final Segmentation of the Iowa River Basin.

If urban runoff does not contribute significant water or pollutants to the study area, it is appropriate to represent the entire watershed with pervious land segments. For example, in the Iowa River Basin between 65% and 85% of each county which contributes land to the basin is cropland, while less than 1% is urban. Of all other land use types, only grassland comprises more than 10% of the area's total land. As a result, agricultural nonpoint source pollution in the form of fertilizers and pesticides is the major water quality concern in the basin. While use of impervious land segments is not necessary to model this study area, differences in land use and agricultural practices require the division of each of the three segment groups of the basin into multiple pervious land segments.

A large majority of the croplands in the basin are planted in either corn or soybeans. Given the differences in fertilizer and pesticide application for the two crops, each crop was considered as a separate land-use type. All lands not planted in corn or soybeans were considered as a third composite land-use type. Thus, there were a total of nine pervious land segments (PLSs) for the Iowa River Basin - one to represent each of the three land-use types in each of the three segment groups. The characteristics of the nine pervious land segments selected for the Iowa River Basin simulation are summarized in Table 3.4.

Division of segment group areas into PLS areas. A number of factors are involved in deciding how many and which land uses will be modeled as distinct segments. Important considerations include:

- allowable complexity of modeling effort within time and effort constraints of the study
- spatial resolution required to answer study questions
- number of segment groups required to represent differences in meteorologic, topographic, and soils conditions
- degree of heterogeneity in land use within segment groups
- availability of reliable data which will serve as the basis for dividing segment groups into desired segments

When the model user has decided upon an appropriate number of land use segments based on the above considerations, a good deal of work is still required to transform and reduce

TABLE 3.4 DEFINITION OF PERVIOUS LAND SEGMENTS FOR THE IOWA RIVER BASIN

	CHARACTERISTICS		
PLS#	meteorology	soils	land use
1	met. set # 1*	loess	soybeans
2	met. set # 1	loess	corn
3	met. set # 1	loess	other
4	met. set # 2	glacial till	soybeans
5	met. set # 2	glacial till	corn
6	met. set # 2	glacial till	other
7	met. set # 3	glacial till	soybeans
8	met. set # 3	glacial till	corn
9	met. set # 3	glacial till	other

* see Table 3.3 for description of meteorologic data

existing land-use data into the form needed as input to HSPF. Depending on the size of the study area, local, county, and/or state statistics and planning maps may be necessary to properly characterize land use. For large watershed areas, land-use data is often tabulated on a county-by-county basis, and this data must be extrapolated to contributing areas to each reach based on the amount of various counties contained within each contributing area. At the same time land-use data in existing documents quite often is divided into different categories than those desired for the modeling study. Consequently, some aggregation or disaggregation of data is almost always required.

For the Iowa River Basin Study, county land use data for one year (1976) of the simulation period (1974-1978) was reduced to determine the percentage of land in each county devoted to corn, soybeans, and other purposes. It was assumed that the relative amount of land devoted to each use was constant throughout the county. The contributing area to each hydraulic reach was subdivided on a county basis, and further subdivided into corn, soybeans, and other land based on the countywide statistics. Total area devoted to each of the land uses is summarized in Table 3.5 for each of the 13

TABLE 3.5 LAND USE IN THE 13 CONTRIBUTING AREA SUBDIVISIONS IN THE IOWA RIVER BASIN

Reach	Contributing area (sq km)	Area planted in corn (sq km)	Area planted in soybeans (sq km)	Other land use (sq km)
1	860	321	111	427
2	847	332	140	376
3	355	140	60	155
4	269	106	47	117
5	238	98	41	98
6	723	337	117	269
7	927	445	197	285
8	995	495	259	241
9	122	62	28	31
10	202	101	49	52
11	199	98	54	47
12	391	184	129	78
13	1109	523	360	225
TOTAL	7236	3243	1593	2400

subdivisions of the basin. (Note that all land in the drainage area for a reach must be classified as belonging to one of the land use categories.) The information in this table, combined with parameter values which establish hydrologic and water quality characteristics for each land-use type, is needed by HSPF in order to simulate runoff and chemical washoff from contributing areas (if a reach system is being modeled) or from segment groups (for studies not including reach systems).

Transferring Land Segmentation Data into a HSPF Input Sequence. The following explanations describe how the meteorologic, soils, and land-use data used to define land segments are incorporated into the HSPF input sequence (User's Control Input):

1. Meteorologic data are input to the Time Series Store (TSS) using the procedures outlined in Section 4 of this guide and detailed in Part F of the User's Manual.

2. After the meteorologic data have been input and cataloged in the TSS, the modeler specifies which weather data will be used for each land segment by developing the EXTERNAL SOURCES BLOCK of the User's Control Input (see Appendix A for example).

3. Soil properties such as particle size and distribution, bulk density, depth of topsoil, and others are critical determinants of the hydrologic and sediment erosion processes on pervious land segments. Consequently, the values selected for many of the parameters in the User's Control Input for module sections PWATER, MSTLAY, and SEDMNT are determined by the predominant soils characteristics for each segment.

4. Land use activities affect hydrologic, sediment, and chemical processes on all land segments, regardless of whether they are pervious or impervious. Representation of land use activities is accomplished through the use of the PWATER, SEDMNT, MSTLAY, PQUAL, PEST and NUTR module sections of PERLND and the IWATER, SOLIDS, and IQUAL module sections of IMPLND. In addition, the 'Special Actions' option (see User's Manual Section 3.5 and Sections E 4.03 and F 4.10) is used to represent chemical applications, tillage operations, and other abrupt changes to land surface conditions.

Selecting appropriate parameter values to represent various soil types and land-use activities is a major aspect of simulation. Additional discussion on specific PERLND and IMPLND parameters and their relationships to land surface and subsurface conditions is provided in Section 6 (Model Parameters and Parameter Evaluation).

3.4 Segmentation and Characterization of the Channel and Contributing Areas

The purpose of this section is to outline and discuss the criteria used for selection and definition of channel reaches and the areas contributing runoff to the reaches. Performance of the tasks described in this section is only necessary if the model user decides that modeling of hydraulic routing and/or instream processes is essential to meet the study goals. Situations which often require modeling of channel processes include:

- studies which require the calculation of accurate instantaneous peak flows and/or concentrations

- studies in which point loadings must be considered

- studies in which water quantity and/or quality results must be determined at locations other than the downstream terminus of the study area

- studies which simulate constituents which experience significant degradation in the stream channel during ordinary flow conditions

Basic channel hydrogeometry is a primary consideraton in the channel segmentation process. Before the segmentation process begins, the modeler should determine the following channel characteristics from available maps and supporting data:

- length of channel in study area (from maps or reports)

- average slope of channel (from maps or reports)

- velocity at mean flow (from USGS gage records)

- flow-through time for mean flow

The above data gives the model user a rough idea of the actual channel behavior. For example, by comparing flow-through time for mean flow for the study channel to the degradation rate for a particular contaminant, one can assess whether or not channel processes should be expected to significantly reduce quantities of the contaminant during the travel time in the study area. Such information allows the modeler to more clearly define the processes important to the modeling effort before simulation begins.

General channel characteristics such as average slope are useful indicators of required segmentation. By comparing average slope to extremes in slope experienced in localized portions of the channel, one can ascertain whether or not hydraulic behavior is likely to vary significantly from one length of channel to another; if so, additional channel segmentation may be required to provide a hydraulic representation which is adequate to satisfy study goals. The proper use of hydrogeometric considerations in the segmentation process was demonstrated by the Iowa River Study in which the three major criteria for definition of channel reaches were reach length, slope, and entry point of tributary flow.

(1) Reach length. The hydraulic routing algorithms used in HSPF are most accurate when flow time through individual reaches approximates the simulation time step. Since a 2-hour time step

was used for routing in the Iowa River, reach lengths should ideally have been approximately 3.6 km (1.8 km/hr x 2 hours) in order for flow-through time for mean flow to meet this condition. If this criterion were followed, more than 80 reaches would have been necessary for the Iowa River channel. For the purpose of this demonstration project longer reaches, in the range of 15 to 30 kilometers, were used. The use of longer reaches reduced and spread out short time interval peaks, but effects were minimal on the mean daily values used for calibration.

(2) Slope. Individual reaches should have reasonably homogeneous bottom slope. Major drops in bottom elevation due to natural falls or reservoirs should serve as boundaries between reaches; the change in bottom elevation at the channel discontinuity should not be considered in the slope calculation.

A low water profile for the Iowa River was prepared using U.S.G.S. data (Heinitz, 1973). The profile (Figure 3.7) indicated a highly uniform slope for the entire 300 km stretch of river. A preliminary division of the river into reaches indicated that slopes range from 0.00026 to 0.00069 m/m. Consequently, slope was not a major consideration in reach definition for the Iowa River. U.S.G.S. data indicated only one significant discontinuity in the channel bottom: a 24-foot drop below the Iowa Falls Power Dam (Figure 3.7). The reservoir site was used as a reach boundary in definition of the Iowa River reach configuration.

(3) Entry point of tributary flows. HSPF assumes that all local flows enter a reach at the upstream boundary. Consequently, it is reasonable to define reaches so that downstream limits are located directly above major tributary inflows. Hence, inflows enter a reach at its upstream limit in the same manner as the routing algorithms assume.

The Iowa River was divided into 13 reaches for simulation. Of the 12 intermediate reach boundaries between the study limits, one was selected at the Iowa Falls Power Dam channel

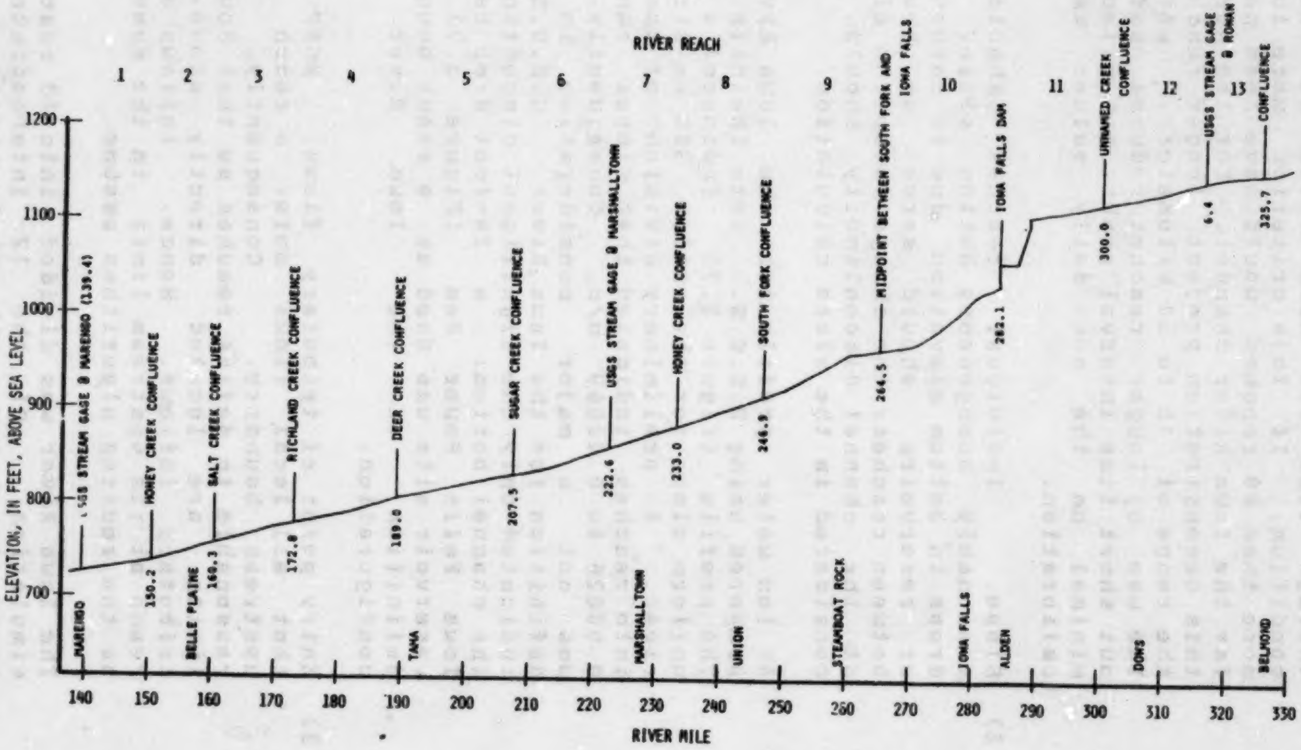

Figure 3.7 Iowa River Low-Water Profile

discontinuity, 2 were selected at U.S.G.S. streamflow gage sites (Rowan and Marshalltown), eight corresponded to sites of major tributary inflow, and one was chosen to subdivide a section of river which was too long to be represented as one reach.

While channel segmentation in the Iowa River Study was based almost solely on hydrogeometric criteria, additional considerations are important in many other studies. Two factors which are critical to the development of an appropriate reach configuration are (1) the location of data available for model calibration/verification and (2) the spatial resolution required to answer study questions.

Data Availability. As discussed in Section 3.2, the period of simulation should be selected based not only on availability of meteorologic data, but also on the availability of instream quantity and quality data which can be used for calibration/verification. A good instream calibration depends on one or more reliable streamflow records which extend over the entire period selected for calibration/verification. If water quality is to be simulated, instream data on chemical concentrations which characterize both spatial and temporal variation is highly desirable. In order to compare observed and simulated values directly, it is useful to define model reaches so that points where data have been collected correspond to reach boundaries. When the model user has decided which quantity/quality data will be used for calibration/verification, the location of this data should be considered in the channel segmentation scheme. Segmenting the channel so that streamflow gages are located at reach boundaries is a common practice.

Spatial Resolution Requirements. The spatial detail of simulation results is determined by the number and length of the reaches defined in the channel representation. If the modeler wishes to isolate individual point loads for detailed analysis, no more than one point load can be contained in a single reach. If the localized effects of an instream aerator are to be assessed, the reach containing the aerator should be a short one; otherwise, calculated increases in dissolved oxygen will be averaged over a longer stretch of channel than desired. In general, reach boundaries should be defined at each point where simulation results need to be examined. For example, if the goal of a study is to assess a number of potential reservoir sites, a reach boundary should be defined at each of the sites.

When the model user has developed an appropriate reach segmentation scheme based on channnel hydrogeometry, data availability, and spatial detail requirements, a number of supporting calculations and tasks must be performed as outlined below:

(1) Delineate the study area boundary and the stream channel on the best available topographical map.

(2) Locate reach boundaries on the map.

(3) Delineate the watershed area contributing runoff to each of the reaches.

(4) Using a planimeter or other methods, calculate the area contained in each of the subdivisions delineated in step #3.

(5) Determine the average slope of each reach based on map contours or supporting data.

(6) Concurrent with the final land segmentation effort described in Section 3.3, determine whether it is reasonable to superimpose land segment boundaries on contributing area boundaries to simplify the modeling effort.

(7) Develop an FTABLE for each reach for use in the HSPF input sequence. FTABLES specify values for surface area, reach volume, and discharge for a series of selected average depths of water in the reach. In most cases this type of information is not available for each reach and some approximations must be performed. Description of FTABLE development for the Iowa River Basin Study is provided below as an example.

FTABLES for reaches 1, 7, and 13 were developed using U.S.G.S. cross-sections at gage sites and depth/discharge curves, combined with specified reach lengths. FTABLES for reaches 2 through 6 were developed assuming that the slopes of the cross-sections were the same as that at Marengo, but that channel capacity decreased upstream from reach to reach. Both the width and depth coordinates of points on the Marengo cross-section were multiplied by a factor (<1.0) consistent with relative top width data developed by Wallace (1971) for each of the reaches along the Iowa River. The adjusted cross-sections were input to an auxiliary computer program along with values for channel slope, Manning's n and flow. The program generated values for normal depth, cross-sectional area, and top width for a series of flow values at each reach cross-section, providing all the hydraulic data necessary to generate the FTABLES. The same procedure was used to develop FTABLES for reaches 8 through 12 based on the cross-section and slope at Rowan. Again, channel capacity was increased downstream from reach to reach by applying progressively larger multipliers (based on Wallace's data) to the coordinates of the Rowan cross-section. It should be noted that the Marshalltown cross-section was not used to generate other FTABLES, because its shape was not considered representative of most stretches of the river (Wallace, 1971).

(8) Prepare a summary table including reach designation numbers, lengths, average channel slopes, and contributing areas. Table 3.6 from the Iowa River Basin Study is provided as an example of such a summary table.

Transferring Channel Characterization and Segmentation Data into a HSPF Input Sequence. The three major groups of input data developed during the channel segmentation and characterization effort are (1) the hydraulic data contained in FTABLES, the contributing areas to reaches, and the configuration of the reach network. The following guidelines are provided in order to expedite the incorporation of this data into a HSPF input sequence:

1. The contents and format of the FTABLES are outlined in Part F (Section 4.5) of the User's Manual, and typical FTABLES are included as part of the sample input sequence in Appendix A of this guide.

2. Contributing area data for each reach is incorporated into the input sequence in the MFACTR field of the NETWORK Block. Refer to Part F (Section 4.6) of the User's Manual for instructions or to Appendix A of this guide for an example. (Note that the value of MFACTR is dependent on the constituent units used in both the PERLND/IMPLND and the RCHRES application modules.

TABLE 3.6 REACH CHARACTERISTICS FOR THE IOWA RIVER

Description of Reach	Reach No.	Reach Length (km)	Channel Slope (m/m)	Contributing Area (sq km)
Belmond to Gage at Rowan	13	15.0	.00026	1109
Gage at Rowan to Unnamed Creek Confluence	12	26.4	.00031	391
Unnamed Creek Confluence to Iowa Falls	11	28.8	.00066	199
Iowa Falls to Midpoint	10	28.3	.00069	202
Midpoint to South Fork Confluence	9	28.3	.00055	122
South Fork Confluence to Honey Creek Confluence	8	22.4	.00044	995
Honey Creek Confluence to Gage at Marshalltown	7	16.7	.00047	927
Gage at Marshalltown to Sugar Creek Confluence	6	24.3	.00033	723
Sugar Creek Confluence to Deer Creek Confluence	5	29.8	.00028	238
Deer Creek Confluence to Richland Creek Confluence	4	26.1	.00030	269
Richland Creek Confluence to Salt Creek Confluence	3	20.1	.00032	355
Salt Creek Confluence to Honey Creek Confluence	2	16.3	.00030	847
Honey Creek Confluence to Gage at Marengo	1	17.4	.00026	860
TOTAL		299.8	.00044	7236

3. The configuration of the reach network is also specified in the NETWORK Block of the UCI. Flow of water and constituents from upstream reaches and contributing land areas for each reach are included in this portion of the UCI. Further details on the use of the NETWORK Block to specify transfer of materials from land segments to the channel are included in Appendix B of this guide.

When the tasks outlined in the previous four sections (3.1-3.4) have been accomplished, the modeling strategy for most model applications is complete, and the modeler can begin to develop the computer data base and input sequences for the preliminary simulation runs. However, when HSPF is used to model certain discrete activities, such as pesticide or fertilizer applications on farmland, additional effort must be expended on the modeling strategy to develop an appropriate model representation. The next section describes how and when to use the Special Actions routine of HSPF to model the effects of discrete events occurring on the study area.

3.5 Characterization of Special Actions

The model user should be aware of the Special Actions capabilities of HSPF during the development of the modeling strategy. The Special Actions Block can be used to adjust the value for any variable in the COMMON BLOCK (operation Status Vector) of module section PERLND at any point in time during the simulation period. Among the situations in which this capability can prove useful are the following:

(1) Representation of natural events which are not adequately portrayed by model algorithms.

(2) Representation of discrete man-made events or impacts.

(3) Control of output for critical periods.

Using the Special Actions Block to account for a process in nature is essentially a corrective action necessitated by observed deficiencies in the algorithms used to represent the process. For example, in some model applications the standard practice of inputting a constant value for infiltration capacity is not appropriate. Since freeze or thaw of the ground alters the infiltration and storage capacity of soil, seasonal adjustment of the infiltration capacity parameter (INFILT) may be required in order to adequately model the seasonal differences in runoff generation due to ground conditions (Donigian et al., 1983a).

Many activities related to agriculture, silviculture, construction, and mining can have significant effects on the hydrologic and water quality processes considered by HSPF. The influence of such activities on modeled processes can be represented by using the Special Actions Block to modify the values of key parameters and/or variables of the PERLND module section at appropriate points in time during the simulation period. The Iowa River Basin Study included a number of situations in which the Special Actions capability was utilized to represent the effects of agricultural activities. One example was increasing the value for the detached sediment storage whenever plowing occurred; this adjustment was critical to the results for watershed sediment washoff simulation. Another example was increasing the values for land surface and soil storages of fertilizers and/or pesticides to represent chemical application during the simulation period. Those interested in using the Special Actions Block to model agricultural activities are referred to reports on parameter estimation for modeling agricultural BMPs (Donigian et al., 1983a) and study descriptions for application of HSPF to Four Mile Creek, Iowa (Donigian et al., 1983b) and the Iowa River Basin (Imhoff et al., 1983).

While the Special Actions Block was originally introduced into HSPF in order to allow the modeling of agricultural activities such as plowing, cultivation, fertilizer and pesticide application, the ability to alter the value of variables at intermediate points during the simulation period can be used in a number of creative and effective ways. In one study the Special Actions Block was used to increase the values for chemical storage variables associated with rainfall. Since HSPF (Release No. 7) does not model the quality of precipitation, chemical storage values were increased on a monthly basis commensurate with the quantity of rainfall and associated chemicals occurring each month. In another case a model user employed the Special Actions Block at an intermediate point during the simulation to alter the value of the parameter which specifies the print interval for output; by doing so it was possible to generate the detailed output necessary to understand results from a critical period of simulation without printing unnecessary information during the remainder of the simulation period.

It is important for the model user to consider whether or not the use of the Special Actions Block to alter values of variables used in the PERLND module section can improve the model representation of the physical processes which are being simulated. If so, Section 4.03 of Part E and Section 4.10 of Part F of the User's Manual provide the necessary details to utilize this option. The proper input format for Special Actions instructions is further illustrated in the sample input sequence contained in Appendix A.

SECTION 4

OPERATIONAL ASPECTS OF HSPF USE

The third step to applying HSPF is familiarizing oneself with the mechanics of the model so that the input sequences necessary to build the timeseries data base (Time Series Store) and execute simulation runs can be developed.

While creation and modification of input sequences will be a continuing process throughout the later stages of model application, it is useful, particularly for the new model user, to study and understand the general operational aspects of HSPF prior to attempting to use the model. Preliminary knowledge of HSPF operations will allow the user to eliminate much of the cost and frustration involved in a trial-and-error approach to running the model. The goal of this section is to provide an overview of considerations involved in running HSPF and developing input sequences, and to direct the user to the proper places in the User's Manual for additional information.

4.1 Steps in Running HSPF

A necessary first step prior to actually running HSPF is to obtain the current version of the program. The complete HSPF system including source code, documentation, and stand-alone programs is available on tape from the U.S. EPA, and may be obtained by writing to:

Center for Water Quality Modeling
U.S. Environmental Protection Agency
College Station Road
Athens, GA 30613

The distribution tape includes the following files:

- source code for HSPF
- input sequence to compile HSPF
- object code for HSPF
- input sequence to link HSPF
- HSPF Information File (INFOFL)
- HSPF Error File (ERRFL)
- HSPF Warning File (WARNFL)

- HSPF test input
- HSPF test output
- lists of HSPF subroutines (by no. and alphabetically)
- HSPF User's Manual (text only)
- HSPF OSV's and data structures
- PERLND variable memory addresses (for use in SPECIAL ACTIONS)
- source code for NEWTSS
- IBM input sequence to compile and link NEWTSS
- NEWTSS INFOFL
- NEWTSS ERRFL
- NEWTSS test input
- NEWTSS test output
- FTABLE generation program

Once this tape is obtained and the necessary files have been transferred to the user's computer system, the following steps in actually running HSPF are required: (1) compilation and testing of HSPF and NEWTSS, (2) creation of the Time Series Store (TSS), (3) development and running of input sequences, and (4) analysis of the results. The compilation and testing process will be unnecessary if HSPF is already operational on the user's computer or on another system. Otherwise, the HSPF source code (available on the distribution tape) is required, and must be compiled, linked, and tested. For installation on computer systems other than IBM, the user may have to modify the source code according to system specific instructions available from the U.S EPA (Athens, GA). HSPF has been sucessfully operated on a variety of computer systems, such as IBM, DEC VAX, CDC, HP3000, and Harris.

Creation of the TSS involves the actual creation of a TSS file using the stand-alone program NEWTSS, creation of individual dataset labels in the TSS with the TSSMGR module, and subsequent input of data (time series) to the TSS using the COPY and/or MUTSIN modules. This process is described in detail in Section 5.0 of this document.

Developing and running input sequences, and analysis/display of the results using the various capabilities and options of HSPF are the primary operational aspects to be considered in this section.

4.2 Overview of HSPF Input

HSPF input sequences consist of the required job control language (JCL) and one or more HSPF 'input sets'. An input set is either a TSSMGR input set used to create, modify, or destroy labels of individual datasets in the TSS, or a RUN input set, used to perform all other operations of HSPF.

The input set is further divided into groups of text lines (card images). The groups are called 'blocks' and may appear in any sequence in a run; however, a natural or logical sequence exists, and will be presented here as an example. Both the new and experienced HSPF user will find this sequence useful for operational purposes, i.e. ease of development and modification, and also for understanding and presentation.

Table 4.1 lists the various blocks of an HSPF input sequence with reference to the corresponding section(s) in the User's Manual where additional information and guidance in the development of that block's input is available. Of course, a single input sequence or set would not often include every block; however, a RUN input set must include the GLOBAL and OPERATION SEQUENCE blocks, at least one OPERATION-type block (PERLND through MUTSIN in Table 4.1), and one of the three time series transfer blocks (EXTERNAL SOURCES, NETWORK, EXTERNAL TARGETS). A TSSMGR input set must include at least one of the TSSM operational blocks. Several sample HSPF input sequence outlines are shown in Table 4.2; each set is a list of the blocks required or typically found in a different type of input sequence. In addition, a short description of the run or its function(s) is included. An example of a complete HSPF input sequence is included as Appendix A of this document.

The development and manipulation of complex input sequences for HSPF can be a time-consuming process due to the large number of user options available. The following list of recommendations is intended to assist the user in this task and to facilitate error detection and isolation.

Input Sequence Development

- Consult pertinent sections of the User's Manual (User's Control Input) for the appropriate format, create an outline of the run consisting of the required "blocks", following the sequence given in Table 4.1.

- Add the required input tables (see Part F, Section 4.4) for each block including all known parameter values or an easily recognizable dummy value (e.g., 'xxxx') where the value is to be inserted later.

- Freely include comment lines (delineated by 3 astericks - ***) in the input sequence to explain options used, default values assumed, parameter value units, and to delineate the input format. Use the comments included in Part F of the User's

TABLE 4.1 HSPF INPUT BLOCKS AND RECOMMENDED SEQUENCES

Block	User's Manual Reference(s)
RUN Input Set	
JCL *	none (use examples on distribution tape)
GLOBAL Block *	F 4.2
OPERATION SEQUENCES Block *	F 4.3
SPECIAL ACTIONS Block	F 4.10, E 4.03
PERLND Block	F 4.4(1), E 4.2(1)
IMPLND Block	F 4.4(2), E 4.2(2)
RCHRES Block	F 4.4(3), E 4.2(3)
FTABLES Block	F 4.5,
COPY Block	F 4.4(11), E 4.2(11)
PLTGEN Block	F 4.4(12), E 4.2(12)
DISPLY Block	F 4.4(13), E 4.2(13)
DURANL Block	F 4.4(14), E 4.2(14)
GENER Block	F 4.4(15), E 4.2(15)
MUTSIN Block	F 4.4(16), E 4.2(16)
EXTERNAL SOURCES Block	F 4.6.1, 4.6.2, 4.6.5
NETWORK Block	F 4.6.1, 4.6.3, 4.6.5
EXTERNAL TARGETS Block	F 4.6.1, 4.6.4, 4.6.5, 4.6.6
TSSMGR Input Set	
JCL *	none (use examples on distribution tape)
ADD Block	F 2.3
UPDATE Block	F 2.4
SCRATCH Block	F 2.5
EXTEND Block	F 2.6
SHOWSPACE, SHOWDSL, and SHOWTSS Blocks	F 2.7

* - Always required

Manual or simply modify a sample input sequence included on the distribution tape.

- When modifying an input sequence, user options for specific operations may be easily removed by deleting the corresponding entry in the OPERATIONS SEQUENCE block or making it a comment line. The corresponding input tables for that option may be left intact, or for clarity, they may be deleted or 'commented out'.

- When modifying an input sequence, save the old input sequence file for reference until the subsequent run has been sucessfully executed or until a well defined set of runs has been concluded.

- Maintain a master input sequence file with all blocks and all tables included. This may be used as a base sequence from which a new, functional sequence could be created with minimum effort by merely deleting all unwanted options and adding new parameter/variable values.

TABLE 4.2 EXAMPLES OF INPUT BLOCKS REQUIRED FOR HSPF RUNS

RUN TYPE	BLOCKS REQUIRED	DESCRIPTION
TSSM Label Run	JCL ADD Block	Add label(s) to the TSS
TSS Data Input Run	JCL GLOBAL Block OPER. SEQ. Block COPY Block EXT. SOURCES Block EXT. TARGETS Block	Input time series data to the TSS from a sequential file.
PERLND Run	JCL GLOBAL Block OPN. SEQ. Block SPECL. ACT. Block PERLND Block PLTGEN Block DISPLY Block EXT. SOURCES Block NETWORK Block	Simulate hydrologic and water quality processes on a pervious land segment and output selected time series results graphically and as tables.
RCHRES Run	JCL GLOBAL Block OPN. SEQ. Block RCHRES Block FTABLES Block PLTGEN Block DISPLY Block EXT. SOURCES Block NETWORK Block	Simulate hydraulic and water quality processes in a stream or mixed reservoir reach and output selected time series results graphically and as tables.
Watershed Run	JCL GLOBAL Block OPN. SEQ. Block SPEC. ACT. Block PERLND Block RCHRES Block FTABLES Block PLTGEN Block DISPLY Block DURANL Block EXT. SOURCES Block NETWORK Block	Combination of PERLND and RCHRES runs including plots, durational analyses and tabular displays of selected time series results.

Error Detection

- Interpretation of errors which occur before execution i.e., Run Interpreter errors, may be facilitated by changing the Run Interpreter Output Level to a higher value (maximum = 10) and executing an "interpret only" run. (See references to the Global Block in the User's Manual).

- Detection and isolation of more subtle errors which occur only during execution may be aided by changing the output flags in an operation block to obtain printout of results at each interval or timestep of the run. Cost reductions during this debugging process can be realized by "turning off" all operations and options which are obviously unrelated to the error, and also by limiting the time span of the run. Note that printout of results at each interval will create large volumes of output, so this option should only be used for limited time span runs.

- Warning messages due to mass balance differences in the PERLND module may be caused by operations performed in the SPECIAL ACTIONS Block. For example, chemical applications performed through SPECIAL ACTIONS will generate a mass balance error for the specific chemical state variable modified. The user should examine these warnings and verify their source.

- Error and Warning messages printed with the HSPF output and some additional pertinent information may be found in the HSPF Information File, Error File, and Warning File. The user should have a listing of these files for reference purposes.

4.3 Output Options

Due to the diversity and flexibility of HSPF output options, the user should pay particular attention to this subject in the development of input sequences. Often, analysis of the results of a run may be greatly facilitated and improved by judicious choice of output types and format. The following overview is intended to provide a brief guide to this subject; however, the user should consult the appropriate sections of the User's Manual for more detailed descriptions and for direction in the use of HSPF output options.

The basic output which is available from each of the HSPF physical process operation module sections (e.g., Section

PWATER in module PERLND) may be printed at each time step of the run or at multiple time step intervals including daily, monthly, and yearly summaries. This output basically consists of all state variable values related to the section in addition to detailed material fluxes over the printout interval. The printout frequency is user controlled through the PRINT-INFO tables in the PERLND, IMPLND, and RCHRES input blocks. The user may also specify the units system (English or Metric) used for all printout and output time series through the GEN-INFO tables of these blocks.

In those cases where the user is only interested in specific variables or time series, the selective printing of these time series in the form of "displays" (see below) may be more convenient than the standard output while simultaneously saving printing costs. In addition, for those active module sections which are not pertinent to the run analysis, the user may save printing costs by selectively specifying that no output be produced.

Display Time Series

While the standard output discussed above usually includes much of the necessary information regarding a run, the user may display any time series computed in a run or input to it in a convenient format by using the DISPLY module. In order to determine which time series are computed by each module in a run (and available for output) the user should consult the Time Series Catalog (Part F, Section 4.7 of the User's Manual). Sample outputs from the DISPLY module are shown in Figures 4.1, 4.2, 4.3.

The user can elect to display the data in a "long-span table" or a "short-span table." The term "span" refers to the period covered by each table. A short-span table (Figures 4.1 and 4.2) covers a day or a month at a time and a long-span table (Figure 4.3) covers a year.

The user selects the time-step for the individual items in a short-span display (the display interval) by specifying it as a multiple (PIVL) of INDELT. For example, the data in Figure 4.1 are displayed at an interval of 5 minutes. This could have been achieved with:

INDELT	PIVL
5 min	1
1 min	5

```
                                    TSS 2 Precip. (in/100)
                                    Summary for DAY      1974/ 9/ 2
                                    Data interval:       5 mins

HOUR      SUM                       Interval Number.
                   1        2        3        4        5        6        7        8        9       10       11       12

  3       2.0     .0       .0       .0       .0       .0       .0       .0       .0       .0      1.0       .0      1.0
  4       3.0     .0       .0      1.0       .0       .0       .0      1.0       .0       .0      1.0       .0       .0
  5       5.0     .0       .0       .0       .0      1.0       .0       .0       .0       .0       .0      2.0      2.0
  6       6.0    1.0      1.0      2.0      1.0      1.0       .0       .0       .0       .0       .0       .0       .0
  7       3.0    1.0       .0       .0       .0       .0      1.0       .0       .0       .0       .0       .0      1.0
  8       3.0     .0       .0      1.0       .0       .0      1.0       .0       .0       .0      1.0       .0       .0
  9       3.0     .0       .0      1.0       .0       .0       .0       .0      1.0       .0       .0      1.0       .0
 10       3.0     .0       .0       .0       .0      1.0       .0       .0       .0      1.0       .0       .0      1.0
 11       3.0     .0       .0      1.0       .0       .0       .0       .0      1.0       .0       .0      1.0       .0
 12       4.0    1.0      1.0       .0       .0      1.0       .0       .0       .0       .0      1.0       .0       .0

 13       3.0     .0      1.0       .0       .0       .0      1.0       .0       .0       .0      1.0       .0       .0
 14       2.0     .0       .0       .0      1.0       .0       .0       .0       .0       .0       .0      1.0       .0
 15       4.0     .0       .0      1.0       .0      1.0       .0       .0      1.0       .0       .0      1.0       .0
 16       7.0     .0       .0      1.0       .0      1.0      1.0      1.0      1.0      1.0       .0      1.0       .0
 17       3.0    1.0       .0       .0       .0       .0      1.0       .0       .0       .0       .0      1.0       .0
 18       6.0    1.0       .0       .0       .0       .0      1.0       .0      1.0      1.0       .0      1.0      1.0
 19       5.0    1.0      1.0      1.0       .0       .0      1.0       .0       .0       .0      1.0       .0       .0
 20       3.0     .0       .0       .0       .0       .0      1.0       .0       .0       .0      1.0       .0      1.0
 21       1.0     .0       .0       .0       .0       .0       .0       .0       .0      1.0       .0       .0       .0
 22       1.0     .0       .0       .0       .0       .0      1.0       .0       .0       .0       .0       .0       .0

DAY    SUM : 7.00000E+01
```

Figure 4.1 Sample short-span display (first type) from the DISPLY module of HSPF

If the display interval is less than an hour, an hours worth of data is displayed on one printed "row" (Figure 4.1). The number of items in a row depends on their interval (e.g., 60 for one minute, 12 for 5 minutes, 2 for 30 mins.). A "row" may actually occupy up to 5 physical lines of printout because a maximum of 12 items is placed on a line.

If the display interval is 1 hour, a day's worth of data are displayed on one "row" (Figure 4.2). Again, the number of items in a row depends on the display interval. In this case the entire table spans a month; in the former case it only spans a day.

A long-span table always covers a year; the display interval for individual items in the table is a day (Figure 4.3). The user can select the month which terminates the display (December, in the example) so that the data can be presented on a calendar year, water year or some other basis.

For the purpose of aggregating the data from the interval time step (INDELT) to the display interval, day-value, month-value, or year-value, one of five "transformation codes" can be specified:

Code	Meaning
SUM	Sum of the data
AVER	Average of the data
MAX	Take the max of the values at the smaller time step
MIN	Take the minimum
LAST	Take the last of the values belonging to the shorter time step

SUM is appropriate for displaying data like precipitation; AVER is useful for displaying data such as temperatures.

The DISPLY module incorporates a feature designed to permit reduction of the quantity of printout produced when doing short-span displays. If the "row-value" ("hour-sum" in Figure 4.1; "day-average" in Figure 4.2) is less than or equal to a "threshold value," printout of the entire row is suppressed. The default threshold is 0.0. Thus, in Figure 4.1; data for dry hours are not printed.

The user can also specify:

a. The number of fractional digits to use in a display.

b. A title for the display.

c. A linear transformation, to be performed on the data when they are at the INDELT time interval (i.e., before module DISPLY performs any aggregation). By default, no transformation is performed.

Plot Time Series

One or more time series may also be diplayed graphically using the PLTGEN module, which prepares the time series for plotting; and a stand alone plotting program which reads the prepared plot file and translates its contents into information used to drive a plotting device. User-controlled PLTGEN options include coordinate axis scaling factors, plot and coordinate axis titles, and various curve drawing options. Alternative uses of an HSPF plot file (PLOTFL) are:

1. To display one or more time series in printed form. For example, to examine the contents of a dataset in the TSS, run it through PLTGEN and list

the contents of PLOTFL on a line printer or terminal.

2. To feed time series to some other stand-alone program. For example, one could specify the contents of PLOTFL as input to a program which performs statistical analysis or computes cross correlations between time series.

A stand-alone plot program which will read an HSPF plot file and drive a plotter is required and must be supplied by the user.

Other Time Series Data Utilities

Other analysis capabilities of HSPF involve manipulation and analysis of time series using the GENER and DURANL modules. GENER allows the generation of a new time series by an operation on one or two existing time series. The operation is specified by supplying an "operation code" (OPCODE).

```
                                   TSS 3 Temperature (Deg F)
                                   Summary for MONTH  1974/ 8/
                                   Data interval:    120 mins

DAY      AVER                      Interval Number.
                     1      2      3      4      5      6      7      8      9     10     11     12

  1      63.8     54.5   53.5   52.5   53.0   59.5   68.0   74.5   76.0   74.5   71.0   66.0   62.5
  2      68.8     61.0   60.0   59.0   60.0   65.0   72.5   77.5   79.0   77.5   75.0   71.0   67.5
  3      68.6     65.5   65.0   64.0   64.5   68.5   73.5   77.0   78.0   76.0   70.5   63.5   57.0
  4      64.0     54.5   53.5   52.5   53.5   60.0   69.0   75.5   77.0   75.0   71.0   65.5   60.5
  5      64.9     58.5   57.0   56.0   57.0   62.0   69.5   74.5   76.0   74.0   70.0   64.5   59.5
  6      66.7     57.5   56.0   55.0   56.5   63.5   73.5   80.0   82.0   79.5   73.5   65.0   58.5
  7      66.6     55.5   53.5   52.5   53.5   61.0   71.5   79.0   81.0   79.5   75.5   70.5   66.0
  8      70.3     64.0   63.0   62.0   63.0   68.0   75.0   79.5   81.0   79.0   75.0   69.5   64.5
  9      68.7     62.5   61.0   60.0   61.0   66.0   73.5   78.5   80.0   78.0   73.5   67.5   63.0
 10      69.6     60.5   59.0   58.0   59.0   65.0   74.0   79.5   81.0   79.5   77.0   73.0   70.0
 11      72.8     68.5   68.0   67.0   67.5   71.5   77.5   81.0   82.0   80.0   75.5   69.5   65.0
 12      70.8     62.5   61.0   60.0   61.0   67.0   76.0   81.5   83.0   81.5   77.5   71.5   67.0
 13      70.3     65.5   64.0   63.0   64.0   69.0   76.0   80.5   82.0   80.0   74.0   66.0   60.0
 14      65.5     57.5   55.5   54.5   55.5   62.0   71.0   77.5   79.0   77.0   72.0   65.0   59.0
 15      67.1     56.5   55.5   54.5   55.5   62.5   72.5   79.0   81.0   79.0   75.0   69.5   64.5
 16      70.1     62.5   61.0   60.0   61.0   67.0   75.0   80.5   82.0   80.0   76.0   70.5   65.5
 17      66.8     63.5   62.0   61.0   61.5   65.5   71.5   75.0   76.0   74.0   69.5   63.5   58.0
 18      66.2     55.5   54.0   53.0   54.5   61.5   72.5   79.0   81.0   79.0   74.5   67.5   62.0
 19      70.3     59.5   58.0   57.0   58.5   65.5   76.5   83.0   85.0   83.0   78.5   72.5   67.0
 20      73.8     64.5   63.0   62.0   63.5   70.0   80.0   86.0   88.0   86.0   81.0   74.0   68.0
 21      74.7     65.5   64.5   63.5   64.5   71.0   81.0   87.0   89.0   87.0   81.5   74.0   68.0
 22      73.3     65.0   63.5   62.5   63.0   69.5   78.0   84.5   86.0   84.0   80.0   74.5   69.5
 23      73.4     67.5   66.0   65.0   66.0   71.5   79.5   84.5   86.0   84.0   78.0   70.0   63.0
 24      66.2     60.5   58.5   57.5   58.0   64.0   73.0   78.5   80.0   77.0   71.0   62.0   54.5
 25      64.0     51.5   49.5   48.5   50.0   58.0   70.0   78.0   80.0   78.0   73.5   67.5   63.0
 26      72.9     60.5   59.0   58.0   59.5   67.5   79.5   87.0   89.0   87.0   82.5   75.5   70.0
 27      73.8     67.5   66.0   65.0   66.0   72.5   81.0   87.5   89.0   85.5   78.5   67.5   59.0
 28      60.3     55.0   53.0   51.5   52.0   57.0   64.5   69.5   71.0   69.5   65.5   59.5   55.0
 29      62.7     53.5   52.0   51.0   52.0   58.5   67.0   73.5   75.0   73.5   70.0   65.0   61.0
 30      66.9     59.0   58.0   57.0   58.0   63.5   71.5   76.5   78.0   76.5   73.0   68.0   64.0
 31      67.0     62.0   61.0   60.0   61.0   66.0   73.0   77.5   79.0   76.5   70.5   62.0   55.5

MONTH  AVER: 6.84059E+01
```

Figure 4.2 Sample short-span display (second type) from the DISPLY module of HSPF

Table 4.3 lists the currently available transformations or operations performed by GENER. In Table 4.3, A and B are input time series, and C is the resulting output time series. A typical application of GENER might be the calculation of a chemical concentration by dividing the mass outflow by the water outflow from a reach. The user may also find it convenient to add new operations to GENER by modifying the HSPF source code. For example, a recent application by the Denver Regional Council of Governments, required the incorporation of an "urban irrigation function" which was implemented through the development of a new GENER operation. Further information related to GENER may be found in Part E Section 4.2(15) and Part F Section 4.4(15) of the User's Manual.

DURANL performs duration and excursion analyses on a time series, computing a variety of statistics relating to its excursions above and below certain specified "levels."

```
                               TSS 3 Temperature (Deg F)
                   Annual data display: Summary for period ending 1974/12
Day        JAN      FEB      MAR      APR      MAY      JUN      JUL      AUG      SEP      OCT      NOV      DEC

  1       13.6     21.0     39.8     38.9     49.6     58.9     70.3     63.8     57.9     40.4     63.5     28.7
  2        9.1     15.8     42.2     49.5     51.2     59.9     76.0     68.8     54.9     33.4     55.7     29.8
  3       16.0     14.4     54.7     53.5     50.0     61.2     79.8     68.6     51.7     39.7     54.2     27.5
  4       15.8     12.1     52.2     51.0     45.8     69.6     75.8     64.0     51.8     52.0     42.0     20.7
  5       13.8      6.6     42.5     39.9     45.0     71.0     63.2     64.9     53.5     60.8     36.4     22.5
  6       16.6     13.0     48.3     36.9     38.3     72.2     67.3     66.7     56.1     60.3     37.5     24.6
  7       13.9      8.0     47.8     40.5     39.4     72.4     72.2     66.6     58.6     48.5     39.7     31.0
  8        5.0      6.9     42.4     32.8     44.5     73.0     77.6     70.3     66.0     45.1     43.4     28.7
  9       15.4     14.7     40.6     30.7     40.9     75.7     79.0     68.7     68.2     49.1     44.3     21.3
 10       15.8     16.2     40.1     42.3     47.5     71.2     75.6     69.6     69.8     51.3     46.4     25.5
 11       15.2     17.4     34.4     50.8     50.8     54.9     63.6     72.8     73.5     57.2     54.1     29.4
 12       11.0     31.8     34.3     56.2     50.5     57.1     64.6     70.8     72.7     58.2     40.4     34.0
 13       12.6     31.7     25.2     58.4     43.3     60.6     75.3     70.3     66.1     45.2     33.6     33.6
 14       25.7     17.7     29.8     55.3     57.3     68.4     80.9     65.5     52.4     53.5     27.2     32.3
 15       29.3     13.9     36.2     40.7     58.2     64.5     75.8     67.1     57.0     44.0     26.6     32.8
 16       30.5     23.1     35.5     41.7     52.8     58.8     66.7     70.1     53.8     45.5     31.2     32.2
 17       30.8     24.4     35.5     43.1     60.0     52.3     70.2     66.8     61.4     48.1     41.5     29.0
 18       27.5     26.7     33.8     47.3     55.8     60.4     77.0     66.2     59.0     38.2     45.3     21.2
 19       31.0     33.4     33.2     37.8     57.7     66.5     73.5     70.3     62.7     31.2     44.3     22.7
 20       35.0     31.9     28.7     47.5     57.8     71.1     66.9     73.8     64.7     38.2     41.3     24.8
 21       39.6     36.0     31.1     59.5     67.1     72.3     62.9     74.7     52.8     36.3     35.3     24.8
 22       33.8     34.1     30.2     58.3     71.0     64.4     67.9     73.3     46.1     51.6     36.0     25.4
 23       32.0     20.9     27.6     42.1     61.3     55.0     63.8     73.4     43.6     54.7     45.1     33.4
 24       32.3     13.0     12.3     39.9     56.2     57.0     67.8     66.2     50.9     49.8     44.0     32.3
 25       37.0     16.1     20.3     43.8     52.8     68.4     69.8     64.0     55.3     51.6     27.4     26.0
 26       40.5     24.7     33.2     54.1     51.9     64.3     73.8     72.9     58.7     46.3     21.7     24.4
 27       41.5     36.5     30.9     65.0     50.4     63.5     73.7     73.8     63.8     50.4     26.5     28.3
 28       35.2     43.9     31.4     68.2     55.7     64.3     70.1     60.2     64.5     56.5     28.0     31.0
 29       30.0              30.1     64.4     65.2     66.5     72.2     62.7     57.1     58.4     29.2     33.5
 30       37.6              34.6     60.1     65.1     70.1     65.8     66.9     45.2     64.3     25.7     32.6
 31       35.7              35.6              63.6              64.5     67.0              66.4              30.5

AVER      25.1     21.6     35.3     48.3     53.4     64.6     71.1     68.4     58.3     49.0     38.9     28.2

AVER of monthly values  4.68582E+01
```

Figure 4.3   Sample long-span (annual) display from the DISPLY module of HSPF

Typical applications of DURANL are:

1. Examination of flow modeling results by comparing simulated and observed flow frequency information such as the percent of time the flows exceeded certain specified levels.

2. Analysis of the frequency and duration of dissolved oxygen levels to evaluate aquatic impacts of various waste-load applications or water quality management options.

3. Lethality analysis of chemical concentration time series. The frequency or percent of time acute, chronic, and sublethal conditions (pertinent to a particular aquatic organism) might be determined for a stream from a simulated time series of chemical concentrations.

TABLE 4.3 OPERATIONS PERFORMED BY THE GENER MODULE OF HSPF

OPCODE	Action
1	C= Abs value (A)
2	C= Square root (A)
3	C= Truncation (A) eg. If A=4.2, C=4.0 A=-3.5, C=-3.0
4	C= Ceiling (A). The "ceiling" is the integer >= given value. eg. If A=3.5, C=4.0 A=-2.0, C=-2.0
5	C= Floor (A). The "floor" is the integer <= given value. eg. If A=3.0, C=3.0 A=-2.7, C=-3.0
6	C= loge (A)
7	C= log10 (A)
8	C= K(1)+K(2)*A+K(3)*A**2 (up to 7 terms) The user supplies the no. of terms and the values of the coefficients (K).
9	C= K**A
10	C= A**K
11	C= A+K
12	C= Sin (A)
13	C= Cos (A)
14	C= Tan (A)
15	C= Sum (A)
16	C= A+B
17	C= A-B
18	C= A*B
19	C= A/B
20	C= MAX (A,B)
21	C= MIN (A,B)
22	C= A**B

Further information regarding DURANL and its options may be found in Part E Section 4.2(14) and Part F Section 4.4(14) of the User's Manual.

Generally, as the user gains experience with HSPF, and becomes more familiar with the output and analysis options available, he begins to utilize them more fully to improve the analysis of the results. Examples of much of the common types of output used in typical hydrologic/water quality studies of agricultural watersheds may be found by examining the input sequence included as Appendix A of this document. Generally, long-span displays of stream flow both in units of depth over the watershed and flow units (cms) are included along with concentrations of sediments, pesticides and agricultural nutrients, and the corresponding areal loadings of these materials. Typical plots include many of the same quantities. GENER is typically used to generate concentrations which are not computed internally by HSPF. These concentration time series are then displayed using DISPLY or PLTGEN. Of course many of the results used in the calibration/verification process may not be required for the final production runs and may be eliminated to save computation and printing costs in these runs.

SECTION 5

INPUT AND MANAGEMENT OF TIME SERIES DATA

All HSPF simulation runs involve the use and/or generation of data in the form of time series. This section describes the storage, retrieval, and management of time series data using HSPF utility routines, stand-alone programs, and a large random access file known as the Time Series Store (TSS). Topics to be discussed include evaluation of TSS size requirements, creation of a new TSS file, addition of TSS dataset label and directory information, input of time series to the TSS, and general TSS management tools available within the HSPF system. More specifically, this section provides a guide to the user in the execution of the following steps required in any HSPF application where time series data are manipulated.

- Estimate the size of the TSS
- Create a TSS with NEWTSS
- Create individual dataset labels in the TSS with TSSMGR
- Input data to the TSS with COPY
- Input data to the TSS with MUTSIN
- Maintain the TSS with TSSMGR

Where feasible, examples will be presented in order to clarify the discussion, and relevant sections of the HSPF User's Manual will be referenced for additional information.

5.1 Creation of a Time Series Store

The Time Series Store (TSS) provides a convenient library for storage of time series in the HSPF environment. The TSS consists of a single, large, direct access disc file; HSPF subdivides this space into many datasets containing time series, and a directory keeps track of the datasets and their attributes. Before time series are stored in the TSS, the file must be initialized and its directory created.

This is done by executing the separate program NEWTSS which is available on the standard HSPF release tape (Section 4) and documented in Appendix III of the User's Manual. When running NEWTSS, the user specifies general attributes of the TSS file including total size, and Fortran unit number.

An estimate of the amount of data to be stored in the TSS is required to provide a size specification in the NEWTSS input. At the beginning of an application, this estimate may be difficult to make due to uncertainty about exactly what data are both required by the model study and available. However, if the TSS file is discovered to be too small (or large) after it has been set up and filled with data, it is a relatively simple process to open a new TSS file of different size and copy the contents of the current TSS into it. This is accomplished with the COPY option contained in the NEWTSS program.

The first step in estimating the TSS file size is to make an inventory of all available and expected (i.e. simulated) time series data including time step, period of record, source of data, and data format. When a complete inventory of all required data sets has been completed, a simple equation may be used to calculate the TSS size specifications required in the NEWTSS input. Factors required for the equation include the information compiled in the inventory and any pertinent compression information for the various time series. In general, compression of time series data can significantly reduce the amount of space required for its storage if many periods of missing or zero data are present; hence compression options should be utilized whenever feasible. These options are more completely described in Part F Section 2 of the User's Manual, and will be referenced in Section 5.2 of this document. Convenient guidelines including detailed worksheets and instructions are available in Appendix III of the User's Manual to assist the user in both steps of the TSS file size estimation process.

Creation of the TSS file requires the execution of NEWTSS. The NEWTSS input sequence used to create the TSS file for the Iowa River project is shown below as an example, along with a definition of input parameters.

```
OPNTSS
  TSS FILE LENGTH=   960      (TSS file length in records)
  MAX. DSNO=         200      (Maximum number of datasets)
  TSS FILE NO=        18      (Fortran unit number of the
                                TSS file)
```

5.2 Adding Dataset Labels

After the TSS file has been initialized and its directory created using the NEWTSS program, the individual time series are put in the store using HSPF utility routines. This procedure requires two separate steps; first, the HSPF routine known as TSSMGR is employed to create the specific datasets or labels in the TSS, and second, the actual data is copied to the newly created datasets using the COPY and/or MUTSIN routines contained in HSPF.

Before data can be stored in the TSS, individual labels must be created and space allocated within the TSS file. Data in the TSS is stored in "datasets", each of which is identified by a "label". Labels are created or added to the TSS by executing the ADD option of the TSSMGR routine; they include such information as an identifying dataset number, amount of space in the dataset, the unit system of the data, compression information, time step, and descriptive information such as name, location, etc. This information is very important to the correct and efficient storage of the corresponding time series data; the user should carefully review Part F, Section 2 of the User's Manual where the TSSMGR input and user options are described. Note that much of the information needed may already have been compiled during the inventory of time series for evaluating the total size of the TSS (Section 5.1 of this document).

Shown below is an example TSSMGR ADD input sequence which was used to create a dataset label for a streamflow record on the Iowa River. Note that input variables which are not shown will assume their default values.

```
ADD
   DATASET NO =           45
      SPACE=              10
      NAME=           STFLOW
      UNITS=         ENGLISH
      COMPRESSION=    UNCOMP
      TIMESTEP=         1440
      NMEMS=               1
      LOCATION=    MARENGO, IOWA
      MEMBER NAME=    STFLOW
      KIND=             MEAN
```

5.3 Input of Data

Input of data to the TSS is accomplished by executing either a COPY or MUTSIN operation of HSPF depending on the format of the available data. Normally, time series data is available as a sequential file in which a number of successive data points or intervals are contained on each line (card image), and in a particular format. The HSPF system is designed to read such a file using either a default format or a user-specified format. The data is transferred from the sequential file to the TSS dataset by employing the COPY utility module of HSPF. Listed in Figure 5.1 and described below is an example of the input required to transfer two time series into the Time Series Store.

The GLOBAL Block specifies the period for which data are being input (June 1974), and some other general control information.

The OPN SEQUENCE Block indicates that there are two COPY operations in the run, the first having a time step of 1 hour and the second 24 hours.

The COPY Block indicates that, for both COPY operations, a single mean-valued time series is being handled.

The EXT SOURCES Block specifies that:

1. The file with FORTRAN unit no. 31 contains hourly data (format HYDHR), in metric units. Missing records are assumed to contain zeros (like NWS hourly precipitation cards). The multiplication factor field is blank, so it defaults to 1.0. The time series goes to COPY operation no. 1 time series group INPUT, member MEAN 1.
2. The file with Fortran unit no. 32 contains daily data (format HYDDAY) in metric units. This time series goes to COPY operation no. 2.

The EXT TARGETS Block specifies that:

1. The output from COPY operation no. 1 (which came from sequential file no. 31) goes to dataset no. 25 in the TSS (member PRECIP 1) and is stored in metric units. The access mode is ADD.
2. Similarly, the output from COPY operation no. 2 is to be stored in member PETDAT 1 of TSS dataset no. 26.

Note that the labels for the TSS datasets must have been previously created, and that the member identification and unit system information (METR) supplied by the user must agree with the corresponding information in the label.

Figure 5.1   Example of User's Control Input for the COPY Module

```
********************************************************************************
RUN

GLOBAL
  Inputting test data to TSS
  START       1974/06           END    1974/06
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1
END GLOBAL

OPN SEQUENCE
      COPY         1    INDELT 01:00
      COPY         2    INDELT 24:00
END OPN SEQUENCE

COPY
  TIMESERIES
    #thru#  NPT  NMN ***
    1    2         1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>   #   #        <Name> # #  ***

SEQ     31 HYDHR    METRZERO               COPY     1     INPUT  MEAN   1
SEQ     32 HYDDAY   METRZERO               COPY     2     INPUT  MEAN   1
END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***
COPY     1 OUTPUT MEAN   1                 TSS     25 PRECIP 1 METR      ADD
COPY     2 OUTPUT MEAN   1                 TSS     26 PETDAT 1 METR      ADD
END EXT TARGETS

END RUN

********************************************************************************
```

In addition to storage of various input time series data for HSPF simulations, the TSS also provides a convenient storage facility for resulting output time series. Any time series created during an HSPF run is available to be output and stored in the TSS; hence making it available as input to a

future run. For example, one could store the appropriate time series results of a completed hydrologic calibration, and subsequently use them as input to water quality calibration runs thus saving the costs of resimulating the hydrology in each run.

Transfer of output time series to TSS files is specified in the EXT TARGETS Block similarly to the second step of the COPY operation in the previous example (Figure 5.1) except that the time series source is a HSPF simulation operation (e.g. PERLND) rather than a COPY operation. For cases where a number of time series are to be output to a single TSS dataset (either summed or as individual members of the dataset), the time series should first be collected by using a COPY operation (specified in the NETWORK Block) and then output together in the EXT TARGETS Block. For more detailed information on time series linkages, the user should refer to Part F, Section 4.6 in the User's Manual. Also, the time series created by the various simulation modules of HSPF and available to be output are listed in Part F, Section 4.7, the Time Series Catalog.

An alternative method of transferring data to a TSS using the utility module MUTSIN is sometimes required depending on the format of the external sequential file containing the data. MUTSIN is designed to read files which have the same format as an HSPF plot file. Situations in which MUTSIN is useful include the following:

(1) To input data with a time interval not included in the standard HSPF sequential input formats. (Part F, Section 4.9)

(2) To transfer data from one TSS file to another; This transfer requires the use of the PLTGEN utility module to output from the source TSS and MUTSIN to input to the target TSS.

(3) As an interface between HSPF and other continuous simulation models; the other model can output results in the form of an HSPF plot file and MUTSIN inputs the data to a TSS (or an HSPF simulation run).

5.4 Management of TSS Datasets

During the course of a model application study, general maintenance functions associated with the data in the Time Series Store are handled by the TSSMGR module. In addition to creation of dataset labels in the TSS file, this module allows the user to perform general "housekeeping" chores associated with these datasets.

Since the storage of additional data (either model input or output) is often an ongoing process during the course of a model application, the creation of new datasets in the TSS may occur at any time as long as sufficient space exists in the TSS file. As discussed above (see example in Section 5.2), new datasets are created by using the ADD command of the TSSMGR module. This action creates a new label with various user-specified and default characteristics, which is then available for transfer of data.

Often, it becomes convenient or necessary to remove datasets from the TSS. Analysis of data which has previously been input to the TSS or a redefinition of the study goals or strategy may result in the conclusion that a dataset is no longer required. Execution of the SCRATCH command of the TSSMGR module selectively removes the dataset from the TSS thus making the space available for use by another dataset.

Two TSSMGR commands which are used to modify the attributes of a TSS dataset label are the UPDATE and EXTEND options. Use of these commands is required to increase (or decrease) the space allocated to a dataset (EXTEND) or to modify other selected label parameters such as the units, name, location, security parameter, etc. (UPDATE). For example, UPDATE would be used to change the security option of a dataset from WRITE (unprotected) to READ (protected) in order to avoid inadvertent replacement or damage to its contents.

In order to examine the overall status of the TSS and its datasets, one employs the SHOWSPACE and SHOWDSL commands. SHOWSPACE provides a count of the available space in the TSS for additional datasets. The SHOWDSL command displays the attributes of selected or all dataset labels in the TSS and also provides a summary of the TSS data including the period of record (years) contained in each dataset and the available space. The commands used to achieve these and all other functions of TSSMGR are documented in Part F, Section 2.0 of the User's Manual.

SECTION 6

MODEL PARAMETERS AND PARAMETER EVALUATION

For the purposes of HSPF the functional definition of a parameter is an input datum (not a time series) whose value is not changed by program computations. Each parameter supplies the program with information which it needs to perform its operations. Some parameters are control-oriented while others are process-oriented. The control-oriented parameters are used to specify program instructions such as constituents which will be simulated, how long the simulation period will be, or how often program results will be transferred to the line printer. Selecting the best values for these parameters is entirely dependent on the needs of the individual user, and consequently guidelines for their evaluation are not appropriate. The modeler should review Section 4 of this document for a general discussion of user-controlled options in executing HSPF; Part F of the User's Manual contains formatting information for input of parameter values as well as a brief discussion of possible options for each parameter.

This section focuses on the process-oriented parameters needed as input to the application modules of HSPF. Since the model is designed to be applicable to many different watersheds, these parameters provide the mechanism to adjust the simulation for specific topographical, hydrologic, edaphic, land use, and stream channel conditions for a particular area. The large majority of the parameters can be evaluated from known watershed characteristics. Parameters that cannot be precisely determined in this manner must be evaluated through calibration with recorded data.

At the present time the documentation for HSPF does not contain the type of detailed information on parameter evaluation which is available for certain of its predecessor models, such as the Agricultural Runoff Management Model and the Nonpoint Source Model. While developing comparable guidelines for evaluating HSPF parameters on a parameter-by-parameter basis would be a useful task, it is also a formidable one since there are over 1000 parameters in the entire HSPF system. Of course, only a small fraction of these parameters are part of the User's Control Input for any one type of application. The purpose of this section is to familiarize the user with the types of data which are needed for parameter evaluation and to direct the user to existing data and documents which will prove useful in the evaluation process. The section concludes with a general discussion of some of the considerations involved in using and interpreting existing data in order to develop reasonable parameter values for a specific study area.

6.1 Types of Data Needed

Sections 2 and 3 of this document explain how various types of data are used to develop a realistic set of modeling goals and an effective modeling strategy. Much of the data used for these purposes is also useful for evaluating model parameters. Depending on the type of model application, additional information from maps, reports, and research literature may also be needed. While a discussion of data requirements for evaluating individual parameters is beyond the scope of this document, it is nonetheless useful to point out the types of data which are needed to develop the parameters for each section of the three HSPF application modules. Table 6.1 provides a preliminary list of data types needed for each section of PERLND, IMPLND, and RCHRES. Many of the data types listed in the table are sources of raw data. In some cases the information required to evaluate certain parameters may have been developed in previous reports on the study area and use of raw data may not be necessary.

6.2 Sources of Data

Generally speaking, there are a greater number of data sources available for evaluation of physical parameters for a specific study area than there are for evaluation of chemical/biological parameters. This disparity in data availablity is largely due to the fact that physical data related to topograhy, soils, and/or channel geometry are collected as a necessary part of agricultural, silvicultural, construction, and water supply activities whereas collection of the data necessary to evaluate the rates and coefficients involved in chemical/biological interactions is not nearly as widespread. Numerous federal, state, and local agencies may be able to provide information useful in developing values for the physical parameters in HSPF. Among these are:

- U.S. Geological Survey
- U.S. Army Corps of Engineers
- U.S. Soil Conservation Service

- state geologic surveys
- state departments of water resources
- local universities

Although a substantial body of data has been developed on water quality-related parameters, the data are scattered throughout journal articles, government documents and technical reports. This, of course, makes it difficult for the modeler to obtain necessary guidance in assigning values to the various constants and coefficients required by the model. Fortunately, a number of reports and user's manuals have been produced which will assist the user in this process. In particular, the following five sources of information will prove useful in evaluating water quality parameters for HSPF:

- HSPF User's Manual (Johanson et al., 1981)

- ARM Model User's Manual (Donigian and Davis, 1978), NPS Model User's Manual (Donigian and Crawford, 1979)

- Tetra Tech Report: Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Zison et al., 1978)

- CREAMS User's Manual (Knisel, 1980)

- HSPF Iowa Study Reports (Donigian et al., 1983b; Imhoff et al.,1983; Donigian et al., 1983a)

HSPF User's Manual. Parts E and F of the User's Manual are the most useful. Part E contains the functional descriptions for the important processes modeled by HSPF. Included in these descriptions are numerous equations which illustrate how the input parameters are used to adjust the model computations in order to represent specific study area conditions. Part F, the User's Control Input, provides information on how to input necessary parameter values to the computer program.

ARM,NPS User's Manuals. Both of these manuals contain guidelines, on a parameter-by-parameter basis, for evaluation of all process-oriented parameters needed for their use. Since these two models are predecessors of the PERLND and IMPLND modules of HSPF, many of the parameters are shared in common, and the guidelines set down for evaluating particular parameters are equally applicable to HSPF. The names for many of these parameters have been changed to conform to HSPF naming conventions. In order to expedite the use of the valuable information contained in

TABLE 6.1 TYPES AND SOURCES OF DATA NEEDED TO USE THE VARIOUS SECTIONS OF THE HSPF APPLICATION MODULES.

PERLND

SECTION ATEMP	topographical maps
SECTION SNOW	topographical maps, vegetation maps or aerial photos, field observation, ARM User's Manual
SECTION PWATER	vegetation maps or aerial photos, soils maps, topographical maps, land use maps, ARM User's Manual, timing of disturbances
SECTION SEDMNT	soils maps, data on farming practices, ARM User's Manual
SECTION PSTEMP	air temperature data, field soil temperature data
SECTION PWTGAS	none
SECTION PQUAL	local stormwater quality data, NPS User's Manual
SECTION MSTLAY	ARM User's Manual
SECTION PEST	ARM User's Manual, pesticide literature, field data
SECTION NITR	ARM User's Manual, field application rates, kinetic data, crop life cycle
SECTION PHOS	ARM User's Manual, field application rates, kinetic data, crop life cycle
SECTION TRACER	none

IMPLND

SECTION ATEMP	topographical maps
SECTION SNOW	topographical maps, vegetation maps or aerial photos, field observation, ARM User's Manual
SECTION IWATER	aerial photos, stormwater management plans, NPS User's Manual
SECTION SOLIDS	street cleaning data, land use data, local stormwater quality data, NPS User's Manual.
SECTION IWTGAS	air temperature data, water temperature data
SECTION IQUAL	local stormwater quality data, NPS User's Manual

TABLE 6.1 (cont'd) TYPES AND SOURCES OF DATA NEEDED TO USE THE VARIOUS SECTIONS OF THE HSPF APPLICATION MODULES.

RCHRES	
SECTION HYDR	channel geometry data, streamflow gage records and rating curves, topographical maps
SECTION ADCALC	none
SECTION CONS	none
SECTION HTRCH	topographical maps, aerial photos
SECTION SEDTRN	bed sediment data, instream sediment loadings data, particle size analyses
SECTION GQUAL	laboratory or field kinetic data, literature values for partition coefficients, organic matter content of suspended and bed sediments, environmental conditions (e.g. pH, temperature)
SECTION OXRX	literature or field kinetic data, channel bottom samples, instream oxygen and BOD data
SECTION NUTRX	literature of field kinetic data, instream nutrient data, channel bottom samples
SECTION PLANK	literature or field kinetic data, instream biotic data
SECTION PHCARB	none

the ARM and NPS User's Manuals, a table which equates former parameter names with the current HSPF names for selected parameters is included in Appendix C of this document. The names for hydrology and sediment related parameters (i.e., the first two pages) are shared by both the ARM and NPS models, while the remainder of the parameter names in the appendix are specific to the ARM Model.

Tetra Tech Report: Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling. This document is a comprehensive compilation of data on surface water quality modeling formulations and values for rate constants and coefficients. The report contains a literature review covering a broad spectrum of physical, chemical, and biological processes and formulations. Currently, it is one of the best sources available for evaluating many of the parameters related to the instream processes modeled by RCHRES.

CREAMS User's Manual. CREAMS is a mathematical model developed by the U.S. Department of Agriculture to evaluate nonpoint source pollution from field-sized areas. Volume II of the CREAMS documentation (all three volumes are bound as one report) provides the user with guidelines for developing parameter values associated with hydrology, sediment, nutrient, and pesticide simulation. Parameters are organized in tabular form, and for each parameter a short definition, the best source for evaluating the parameter, and the expected quality of the derived value are listed. These tables can provide useful suggestions for evaluating similar HSPF parameters. However, before using parameter values from CREAMS or any other model as input to HSPF, one should compare the model formulations in which the parameters are used. In the case of the CREAMS model, documentation in Volume I should be reviewed to make certain that parameter definitions are consistent with those used in HSPF.

HSPF Study Reports. The Four Mile Creek and Iowa River Reports contain a number of tables which list the values of parameters used in each study. While the values for some parameters may vary greatly from one watershed to another, these two reports will provide a basis for a first guess in developing values for certain parameters. More detailed evaluation guidelines and additional values for runoff, sediment, and chemical parameters are contained in Section 4 of the report entitled "HSPF Parameter Adjustments to Evaluate the Effects of Agricultural Best Management Practices (Donigian et al., 1983a)." In many cases the specific parameter values in this report are pertinent only to the Iowa-Cedar River Basin, while the guidelines describe how to estimate parameter values for other areas or conditions.

The reports and manuals described above give some guidance in parameter evaluation and in some cases provide a range of reasonable values for individual parameters: nonetheless local field data is still the most reliable means of parameter evaluation. The modeler should carefully review the reports and documents which have previously been prepared for the study area to insure that data useful in parameter evaluation is not overlooked.

6.3 General Considerations

Selecting parameter values almost always requires considerable interpretation and/or extrapolation of data. Given the scarcity of definitive guidelines, engineering judgement and a good understanding of model algorithms are crucial to the process. The modeler should keep the following points in mind while performing this task. A number of the points discussed are adapted from the Tetra Tech report cited in Section 6.2.

(1) Selection of reasonable values for physical parameters is a critical first step to all model applications. If the physical attributes of the study area are not represented correctly and with adequate detail, it will be difficult to perform a realistic hydrologic simulation, and without good hydrologic results it is not possible to obtain reliable sediment or water quality results.

(2) Values for a number of parameters, in particular physical parameters, vary on a seasonal basis. When attempting to develop values for parameters related to rainfall interception, upper zone water storage capacity, land surface roughness, interflow, or evapotranspiration from the soil profile, remember that it may be appropriate to develop values on a monthly basis. One should also assess which parameters, if any, are affected by activities on the land surface which are not specifically modeled by HSPF. It may be desirable to modify values for certain parameters coincident with a particular activity by using the Special Actions Block (Section 3.5). If so, the user needs to develop a value for base conditions and one or more additional values representative of the activities which disturb the base condition.

(3) There is rarely concensus on how best to select a value for a particular water quality rate or coefficient. Generally, there are a great many environmental factors influencing a given rate parameter. The factors can be complex, and their influence on rate constants inadequately quantified. In some cases, such as in modeling stormwater runoff quality, there may be so many physical and chemical factors involved that developing a satisfactory mechanistic model may be impractical or beyond the state of the art. In such cases a parameter is often relegated to being a calibration parameter.

(4) The Tetra Tech report cautions against blind use of literature values for parameters, particularly rate parameters, by noting that some researchers believe that some surface water quality parameters are highly system-specific based on the commonly large differences in observed rates from system to system.

SECTION 7

MODEL CALIBRATION AND VERIFICATION

The calibration and verification process is critical to the application of HSPF. In this section ths process will be defined and described, and recommended procedures and guidelines will be presented. The goal is to provide a general calibration/verification methodology for users of the model. As one gains experience, the methodology will become second-nature and individual methods and guidelines will evolve.

7.1 General Calibration Procedures

Calibration is an iterative procedure of parameter evaluation and refinement by comparing simulated and observed values of interest. It is required for parameters that cannot be deterministically evaluated from topographic, climatic, edaphic, or physical/chemical characteristics. Fortunately, the large majority of HSPF parameters do not fall in this category. Calibration should be based on several years of simulation (3 to 5 years is optimal) in order to evaluate parameters under a variety of climatic, soil moisture, and water quality conditions. The areal variability of meteorologic data series, especially precipitation and air temperature, may cause additional uncertainty in the simulation. Years with heavy precipitation are often better simulated because of the relative uniformity of large events over a watershed. In contrast low annual runoff may be caused by a single or a series of small events that did not have a uniform areal coverage. Parameters calibrated on a dry period of record may not adequately represent the processes occurring during the wet periods. Also, the effects of initial conditions of soil moisture and pollutant accumulation can extend for several months resulting in biased parameter values calibrated on short simulation periods. Calibration should result in parameter values that produce the best overall agreement between simulated and observed values throughout the calibration period.

Calibration includes the comparison of both monthly and annual values and individual storm events. Both comparisons should be performed for a proper calibration of hydrology and water quality parameters. When modeling land surface processes, hydrologic calibration must precede sediment and water quality calibration since runoff is the transport mechanism by which nonpoint pollution occurs. Likewise, adjustments to the instream hydraulics simulation should be completed before instream sediment and water quality transport and processes are calibrated. The overall calibration scheme for a model application including hydrology, sediment and water quality simulation is outlined below. The outline is divided into two parts: land surface calibration and instream calibration.

Land Surface Calibration (PERLND, IMPLND).

(1) Estimate individual values for all parameters.

(2) Perform hydrologic calibration run, including snowmelt simulation, if necessary.

(3) Compare simulated monthly and annual runoff volumes with recorded data.

(4) Adjust hydrologic calibration parameters, and initial conditions if necessary, to improve agreement between simulated monthly and annual runoff and recorded values.

(5) Repeat steps 2, 3, and 4 until satisfactory agreement is obtained.

(6) Compare simulated and recorded hydrographs for selected storm events.

(7) Adjust hydrologic calibration parameters to improve storm hydrograph simulation.

(8) Perform additional calibration runs and repeat step 7 until satisfactory storm simulation is obtained while maintaining agreement in the monthly and annual runoff simulation.

If sediment is simulated:

(9) Perform calibration run for sediment parameters.

(10) Compare monthly and annual sediment loss with recorded values, if available.

(11) Compare simulated storm sediment graphs with recorded values for selected events.

(12) Adjust sediment calibration parameters to improve the simulation of monthly and annual values and storm sediment graphs.

(13) Repeat steps 9, 10, 11 and 12 until satisfactory sediment simulation is obtained.

If water quality is simulated:

(14) Perform calibration run for water quality parameters.

(15) Compare simulated monthly and annual pollutant loss with recorded values, if available.

(16) Evaluate pollutant state variables (e.g. surface and soil storages) and compare with recorded data, if available.

(17) Compare simulated and recorded pollutant graphs (concentration and/or mass removal) with recorded data for selected events.

(18) Adjust relevant water quality parameters (i.e. accumulation/washoff pollutant potency, adsorption, decay, leaching and perform additional pollutant calibration trials until satisfactory agreement is obtained.

At the completion of the above steps, HSPF is calibrated to the watershed being simulated under the land use conditions in effect during the calibration period.

Instream Calibration (RCHRES)

(1) Estimate initial values for all parameters.

(2) Perform hydraulic simulation run.

(3) Compare simulated and recorded streamflow hydrographs for calibration period.

(4) If hydraulic routing results do not appear reasonable adjust FTABLE values, and initial conditions if necessary, to improve agreement.

(5) Repeat steps 2, 3 and 4 until satisfactory agreement is obtained.

If water temperature is simulated:

(6) Perform calibration run for temperature parameters.

(7) Compare simulated temperature graphs for calibration period with recorded values, if available.

(8) Adjust temperature calibration parameters to improve agreement between simulated and observed values.

(9) Repeat steps 6, 7 and 8 until satisfactory temperature simulation is obtained.

If sediment is simulated:

(10) Perform calibration run for sediment parameters.

(11) Compare simulated monthly and annual sediment loadings with recorded values, if available.

(12) Compare simulated storm sediment graphs with recorded values for selected events.

(13) Analyze behavior of bed sediments compared to available data.

(14) Adjust sediment calibration parameters to improve the simulation of monthly and annual values and for individual storms.

(15) Repeat steps 10 through 14 until satisfactory sediment simulation is obtained.

If generalized quality constituents are simulated (GQUAL):

(16) Follow the same procedure which was outlined in steps 10 through 15 for sediment.

If dissolved oxygen and BOD are simulated and nutrients and plankton are not:

(17) Perform dissolved oxygen and BOD calibration run.

(18) Assess the effects that parameter values are having on DO and BOD simulations by examining printed output and constituent graphs.

(19) Compare constituent graphs with observed values, if available.

(20) Adjust oxygen parameter values to improve the simulation of both DO and BOD simultaneously.

(21) Repeat steps 17, 18, 19 and 20 until the best agreement between simulated and observed values is obtained for both constituents.

If nutrients are simulated and plankton are not:

(22) Perform nutrient calibration run.

(23) Assess the effects that nutrient parameters are having on DO and nutrient simulations by examining printed output and constituent graphs.

(24) Compare constituent graphs with observed values, if available.

(25) Adjust nutrient calibration parameters to improve the simulation of DO (if nitrification is simulated) and nutrients. If adjustments improve nutrient simulation but harm the DO simulation, consider whether adjustment of DO parameters can compensate.

(26) Repeat steps 22, 23, 24 and 25 until the best agreement between observed and simulated values is obtained for both DO and nutrients.

If plankton are simulated:

(27) Perform plankton calibration run.

(28) Assess effects that plankton simulation is having on dissolved oxygen, BOD, nutrient, and plankton values by examining printed output and constituent graphs.

(29) Compare constituent graphs with observed values if available.

(30) Adjust plankton calibration parameters to improve the simulation of most or all of the affected constituents. Consider adjusting calibration parameters other than plankton parameters, if necessary (i.e., DO, BOD or nutrient parameters).

(31) Repeat steps 27, 28, 29 and 30 until the best agreement between simulated and observed values is obtained for the majority of affected constituents.

If pH and the carbon cycle are simulated:

(32) Follow the same procedure which was outlined for temperature in steps 6, 7, 8 and 9.

At the completion of the above steps, HSPF is calibrated to the channel system being simulated under the conditions in effect during the calibration period. Often times, sufficient data will not be available to complete all steps in the calibration process. For example, monthly and annual values of sediment or pollutants will not be available for comparison with simulated results. In these circumstances, the user may omit the corresponding steps in calibration; however, simulated values should be analyzed and evaluated with respect to data from similar watersheds, personal experience, and guidelines provided below.

7.2 Calibration Guidelines for Major Constituent Groups

The following discussion provides suggestions and guidelines for calibrationg the major constituent groups modeled by PERLND, IMPLND, and RCHRES. In many cases, the guidelines are presented in terms of parameter categories rather than using specific parameter names due to the large number of parameters which must be considered. It should also be noted that when specific parameter names are mentioned, the names used are always those corresponding to the input of a constant parameter value; the user should be aware that in cases where monthly values are input for a particular parameter, the variable names of concern for calibration may be slightly different than those referred to in this discussion.

Hydrologic Calibration

Hydrologic simulation combines the physical characteristics of the watershed geometry and the observed meteorologic data series to produce the simulated hydrologic response. All watersheds have similar hydrologic components, but they are generally present in different combinations; thus different hydrologic responses occur on individual watersheds. HSPF simulates runoff from four components: surface runoff from impervious areas directly connected to the channel network, surface runoff from pervious areas, interflow from pervious areas, and groundwater flow. Since the historic streamflow is not divided into these four units, the relative relationship among these components must be inferred from the examination of many events over several years of continuous simulation. Periods of record with a predominance of one component (e.g., surface runoff during storm periods, or groundwater flow after extended dry periods) can be studied to evaluate the simulation of the individual runoff components.

The first task in hydrologic calibration is to establish a water balance on an annual basis. The balance specifies the ultimate destination of incoming precipitation and is indicated as

$$\text{Precipitation} - \text{Actual Evapotranspiration} - \text{Deep percolation} - \Delta\text{Soil Moisture Storage} = \text{Runoff}$$

In addition to the input meteorologic data series, the parameters that govern this balance are LZSN, INFILT, and LZETP (evapotranspiration index parameter). Thus, if precipitation is measured on the watershed and if deep percolation to groundwater is small, actual evapotranspiration must be adjusted to cause a change in the long-term runoff component of the water balance. LZSN and INFILT have a major impact on percolation and are important in obtaining an annual water balance. In addition, on extremely small watersheds (less than 100-200 hectares) that contribute runoff only during and immediately following storm events, the UZSN parameter can also affect annual runoff volumes because of its impact on individual storm events (described below).

Recommendations for obtaining an annual water balance are as follows:

(1) Annual precipitation should be greater than or equal to the sum of annual evaporation plus annual runoff if groundwater recharge through deep percolation is not significant in the watershed. If this does not occur one should consider using the parameter MFACT in the NETWORK Block to adjust input precipitation so that it is more representative of that occurring on the watershed.

(2) Since the major portion of actual evapotranspiration occurs from the lower soil moisture zone, increasing LZSN will increase actual evapotranspiration and decrease annual runoff. Thus, LZSN is the major parameter for deriving an annual water balance.

(3) Actual evapotranspiration is extremely sensitive to LZETP. Since LZETP is evaluated as the fraction of the watershed with deep rooted vegetation, increasing LZETP will increase actual evapotranspiration and vice versa. Thus, minor adjustments in LZETP may be

used to effect changes in annual runoff if actual evapotranspiration is a significant hydrologic component of the watershed.

(4) The INFILT parameter can also assist in deriving an annual water balance although its main effect is to adjust the seasonal or monthly runoff distribution described below. Since INFILT governs the division of precipitation into various components, increasing INFILT will decrease surface runoff and increase the transfer of water to lower zone and groundwater. The resulting increase in water in the lower zone will produce higher actual evapotranspiration. Decreasing INFILT will generally reduce actual evapotranspiration and increase surface runoff. In watersheds with no base flow component (from groundwater), INFILT can be used in conjunction with LZSN to establish the annual water balance.

When an annual water balance is obtained, the seasonal or monthly distribution of runoff can be adjusted with use of INFILT, the infiltration parameter. This seasonal distribution is accomplished by dividing the incoming moisture among surface runoff, interflow, upper zone soil moisture storage, percolation to lower zone soil moisture and groundwater storage. Of the various hydrologic components, groundwater is often the easiest to identify. In watersheds with a continuous base flow, or groundwater component, increasing INFILT will reduce immediate surface runoff (including interflow) and increase the groundwater component. In this way, runoff is delayed and occurs later in the season as an increased groundwater or base flow. Decreasing INFILT will produce the opposite result. Although INFILT and LZSN control the volume of runoff from groundwater, the AGWRC parameter controls the rate of outflow from the groundwater storage.

In watersheds with no groundwater component, the DEEPFR parameter is used to direct the groundwater contributions to deep inactive groundwater storage that does not contribute to runoff (DEEPFR = 1.0 in this case). For these watersheds, runoff cannot be transferred from one season or month to another, and the INFILT parameter is used in conjunction with LZSN to obtain the annual and individual monthly water balance.

In watersheds with continuous or intermittent baseflow, groundwater outflow to the stream is usually the largest component of the total streamflow. In these watersheds, the DEEPFR parameter is used to estimate the fraction of total groundwater recharge that reaches deep aquifers that do not discharge and contribute to baseflow at the watershed outlet.

Continuous simulation is a prerequisite for correct modeling of individual events. The initial conditions that influence the magnitude and character of events are the result of hydrologic processes occurring between events. Thus, the choice of initial conditions for the first year of simulation is an important consideration and can be misleading if not properly selected. The initial values for UZS, LZS, and AGWS should be chosen according to the guidelines in Section 6 of the NPS User's Manual and readjusted after the first calibration run. UZS, LZS, and AGWS for the starting day of simulation should be reset approximately to the values for the corresponding day in subsequent years of simulation. Thus, if simulation begins in October, the soil moisture conditions in subsequent Octobers in the calibration period can usually be used as likely initial conditions for the simulation. Meteorologic conditions preceding each October should be examined to insure that the assumption of similar soil moisture conditions is realistic.

When annual and monthly runoff volumes are adequately simulated, hydrographs for selected storm events can be effectively altered with the UZSN and INTFW parameters to better agree with observed values. Also, minor adjustments to the INFILT parameter can be used to improve simulated hydrographs; however, adjustments to INFILT should be minimal to prevent disruption of the established annual and monthly water balance. Parameter adjustment should be concluded when changes do not produce an overall improvement in the simulation. One event should not be matched at the expense of other events in the calibration period.

Recommended guidelines for adjustment of hydrograph shape are as follows:

1. The interflow parameter, INTFW, can be used effectively to alter hydrograph shape after storm runoff volumes have been correctly adjusted. INTFW has a minimal effect on runoff volumes. As shown in Figure 7.1 where the values of INTFW were (a) 1.4, (b) 1.8, and (c) 1.0, increasing INTFW will reduce peak flows and prolong recession of the hydrograph. Decreasing INTFW has the opposite effect. On large watersheds where storm events extend over a number of days, the IRC parameter can be used to adjust the recession of the interflow portion of the hydrograph to further improve the simulation.

2. The UZSN parameter also affects hydrograph shape. Decreasing UZSN will generally increase flows especially during the initial portions, or rising limb, of the hydrograph. Low UZSN values are indicative of highly responsive watersheds where the surface runoff component is dominant. Increasing UZSN will have the opposite effect, and high UZSN values are common on watersheds with significant subsurface flow and interflow components. Caution should be exercised when adjusting hydrograph shape with the UZSN parameter to insure that the overall water balance is not significantly affected.

3. The INFILT parameter can be used for minor adjustments to storm runoff volumes and distribution. Its effects have been discussed above. As with UZSN, changes to INFILT can affect the water balance; thus, modifications should be minor.

Adjustment of storm hydrographs is the final step of hydrologic calibration. If the effects of channel

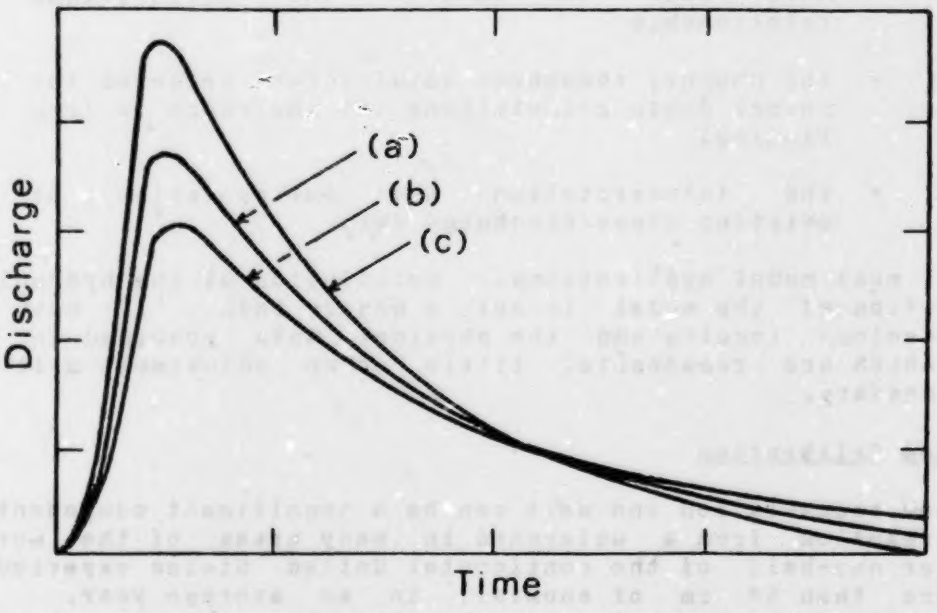

Figure 7.1 Example of Response to the INTFW Parameter.

attenuation on flows are important to the study results, module section HYDR of RCHRES must be used to perform hydraulic routing. If such is the case, the following guidelines are useful for finalizing hydraulic parameter values.

Hydraulic Calibration

The major determinants of the routed flows simulated by section HYDR are the hydrology results from PERLND and/or IMPLND and the physical data contained in the FTABLES (Section 3.4). The FTABLES specify values for surface area, reach volume, and discharge for a series of selected average depths of water in each reach. This information is part of the required User's Control Input for section HYDR and consequently must be prepared prior to running the model. Modification of these FTABLE values is essentially the only means of calibrating the hydraulic results since the additional parameters required for section HYDR are not calibration parameters. If the routed flows simulated by HYDR do not appear reasonable, the user should review the assumptions and approximations on which the FTABLE values were based. Particular attention should be given to the following items:

- the approximations of channel geometry which were used to develop the depth/volume relationship
- the channel roughness coefficients selected for normal depth calculations (if the reach is free flowing)
- the interpretation and extrapolation of existing stage/discharge data

For most model applications, calibration of the hydraulics portion of the model is not a major task. If both the hydrology results and the physical data provided in the FTABLES are reasonable, little or no adjustment will be necessary.

Snow Calibration

Snow accumulation and melt can be a significant component of streamflow from a watershed in many areas of the world. Over one-half of the continental United States experiences more than 60 cm of snowfall in an average year. For mountainous watersheds at high elevations, spring snowmelt may account for the major portion of annual streamflow. Thus, accurate simulation of snow accumulation and melt processes is needed to successfully model many watersheds.

Snow calibration, using module section SNOW, is actually part of the hydrologic calibration. It can be a major part of the hydrologic calibration depending on the importance of snowmelt runoff in the overall hydrologic balance. It is usually performed during the initial phase of the hydrologic calibration since the snow simulation can impact not only winter runoff volumes, but also spring and early summer streamflow.

Simulation of snow accumulation and melt processes suffers from two main sources of user-controlled uncertainty: representative meteorologic input data and parameter estimation. Uncertainties associated with deficiencies in model algorithms, such as representation of frozen ground conditions and effects, are beyond the control of the user in normal applications. However, we recommend that all HSPF users interested in snow simulation review the SNOW module functional descriptions in the HSPF User's Manual and the Iowa Basin studies (Donigian et al., 1983b; Imhoff et al., 1983) in order to be aware of algorithm limitations and assumptions.

The additional meteorologic time series data required for snow simulation (i.e. air temperature, solar radiation, wind, and dewpoint temperature) are not often available in the immediate vicinity of the watershed, and consequently must be estimated or extrapolated from the nearest available weather station. Snowmelt simulation is especially sensitive to the air temperature and solar radiation time series since these are the major driving forces for the energy balance melt calculations. Also, traditional precipitation gages, even when equiped with windshields, can underestimate snowfall amounts by 50 percent or more depending on wind conditions (Linsley et al., 1975). This type of error can have major impacts on the simulation.

Estimation of snow parameters is another possible source of uncertainty due to less historical experience with snow simulation than with general hydrologic modeling. Although the energy-balance approach in module section SNOW is somewhat more deterministic than the PWATER algorithms, a degree of empiricism is still needed for many of the complex processes of snow accumulation and melt. The data and information sources noted in Section 6.2 should be reviewed when estimating snow parameters and should be supplemented with any other relevant information.

In many instances it is difficult to determine if problems in the snow simulation are due to the non-representative meteorologic data or inaccurate parameter values. Consequently the accuracy expectations and general objectives of snow calibration are not as rigorous as for the overall hydrologic calibration. Comparisons of simulated weekly and monthly runoff volumes with observed streamflow during snowmelt periods, and observed snow depth (and water equivalent) values are the primary procedures followed for snow calibration. Day-to-day variations and comparisons on shorter intervals (i.e. 2-hour, 4-hour, 6-hour, etc.) are usually not as important as representing the overall snowmelt volume and relative timing in the observed weekly or bi-weekly period. In many applications the primary goal of the snow simulation will be to adequately represent the total volume and relative timing of snowmelt to produce reasonable soil moisture conditions in the spring and early summer so that subsequent rainfall events can be accurately simulated. Obviously, if snowmelt is a key component of the model application, such as investigating flooding problems from spring snowmelt conditions, more detailed calibration may be needed.

If observed snow depth (and water equivalent) measurements are available, comparisons with simulated values should be made. However, the user should be aware of the possible tremendous variation in snow depth that can occur in a watershed, and that the single observed value may not always be representative of the watershed average.

Guidelines for adjusting snowmelt volumes are as follows:

1. Increasing the SNOWCF parameter should be considered first if snowmelt volumes are underestimated. Maximum SNOWCF values in the range of 1.5 to 1.8 may be appropriate to account for catch deficiency of the gage.

2. If snowmelt volumes are oversimulated there may be problems with the precipitation gage adequately representing the land segment. As discussed in the hydrologic calibration (above), the MFACT parameter in the NETWORK Block can be used to adjust the segment precipitation.

3. Whether precipitation falls as rain or snow has a major impact on resulting runoff volumes. The TSNOW parameter controls this determination. It can be increased if observations consistently indicate that snow occurred and the model assumed the precipitation occurred as rainfall, and vice versa. The Special Actions option in HSPF can be used to adjust TSNOW for specific critical events if necessary for a reasonable simulation.

4. The MPACK parameter has some impact on runoff volumes because low values indicate greater areal coverage of the snowpack. Runoff volumes increase as a function of the area covered by snow.

5. The SNOEVP parameter has a relatively minor effect on snowmelt volumes since snow evaporation is usually a small component of the snowpack water balance. However, unusual conditions may require adjustments to SNOEVP if snow evaporation is important.

Guidelines for adjusting snowmelt timing are discussed below:

1. If significant differences in the timing of observed and simulated snowmelt runoff occur, the user should first examine the meteorologic time series for errors, inconsistencies, and possible discrepancies between the weather station and what the watershed may have experienced. Air temperature and solar radiation are the most critical time series to examine, although wind and dewpoint temperature, to a lesser extent, also affect snowmelt timing. Constant adjustments to the time series are made with the MFACT parameter of the NETWORK Block.

2. The rate at which melt processes occur directly impact the snowmelt timing. Increasing the rate will cause melt to occur earlier in the season, and vice versa. Radiation melt can be adjusted only by adjusting the solar radiation time series as discussed above. Condensation-convection melt can be adjusted either by adjusting the air temperature and wind time series or by the CCFACT parameter, which is a direct multiplier of the condensation-convection melt equation (see HSPF User's Manual).

3. If observed streamflow or snow depth measurements indicate a relatively constant melting of the snowpack, the MGMELT parameter can be used to represent a constant daily melt component. Usually small but non-zero values are used for MGMELT unless specific watershed or meteorologic conditions indicate otherwise.

4. Snowmelt timing in terms of measured runoff can also be affected by the storage and subsequent release of melt water from the snowpack. Increasing the MWATER parameter will increase the amount of melt water stored within the snowpack with a subsequent delay in the snowmelt reaching the watershed outlet or gage.

Unlike predecessor models, HSPF allows the user to run the SNOW module sections independently of the other PERLND modules. In this way, the snow calibration runs can be performed efficiently and cost-effectively on an individual basis prior to executing complete hydrologic calibration runs.

Sediment Erosion Calibration

As indicated in the description of the general calibration process, sediment calibration follows the hydrologic calibration and must precede water quality calibration. Calibration of the parameters involved in simulation of watershed sediment erosion is more uncertain than hydrologic calibration due to less experience with sediment simulation in different regions of the country. The process is analogous; the major sediment parameters are modified to increase agreement between simulated and recorded monthly sediment loss and storm event sediment removal. However, observed monthly sediment loss is often not available, and the sediment calibration parameters are not as distinctly separated between those that affect monthly sediment and those that control storm sediment loss.

In general, sediment calibration involves the development of an approximate equilibrium or balance between the accumulation and generation of sediment particles on one hand and the washoff or transport of sediment on the other hand. Thus, the accumulated sediment on the land surface should not be continually increasing or decreasing throughout the calibration period. Extended dry periods will produce increases in surface pollutants, and extended wet periods will produce decreases. However, the overall trend should be relatively stable. This equilibrium must be developed on both pervious and impervious surfaces, and must exist in conjunction with the accurate simulation of monthly and storm event sediment loss. To assist in sediment calibration, the following guidelines are provided.

1. On pervious areas, KRER, and NVSI are the major parameters that control the availability of sediment on the land surface, while KSER and JSER control the sediment washoff. The daily

accumulation or removal of sediments by NVSI will dominate sediment availability for land surfaces with high cover factors (COVER). On exposed land surfaces, sediment generation by soil splash is important and is controlled largely by the KRER parameter. To offset the sediment availability on pervious areas, the KSER and JSER parameters control sediment washoff to prevent continually increasing or decreasing sediment on the land surface. Thus, balance must be established between the KRER, and NVSI parameters and the KSER and JSER parameters to develop the equilibrium described above.

2. On impervious areas, soil splash is not significant. The major sediment accumulation and removal parameters are ACCSDP and REMSDP and the sediment washoff parameters are KEIM and JEIM. These two parameter sets must be adjusted to maintain a relatively stable amount of sediment on impervious surfaces throughout the calibration period.

3. The output for PERLND and IMPLND indicates the flow and sediment contributions from pervious and impervious surfaces in each land use simulated. In urban areas, the majority of nonpoint pollutants will emanate from impervious land surfaces especially during small storm events and in the early portion of extended events. Pervious land surfaces in urban areas will generally contribute a significant amount of pollutants only during large storm events and the latter portion of extended events. The user should note this behavior from the output provided during calibration runs.

4. The output also indicates the accumulated sediment on pervious and impervious surfaces in each land use. This information is provided to assist in the development of the sediment balance.

5. The daily removal factor, REMSDP, is usually assumed to be relatively constant and fixed. Also, the exponents of soil splash (JRER) and sediment washoff (JSER,JEIM) are reasonably well defined. Thus, the parameters that

receive major consideration during sediment calibration are: the accumulation rates, NVSI and ACCSDP; the coefficient of soil splash, KRER (especially for exposed land surfaces); and the coefficients of sediment washoff, KSER and KEIM.

6. In general, an increasing sediment storage throughout the calibration period indicates that either accumulation and soil fines generation is too high, or sediment washoff is too low. Examination of individual events will confirm whether or not sediment washoff is under-simulated. Also, the relative contributions of pervious and impervious surfaces will help to determine whether the pervious or impervious washoff parameters should be modified. A continually decreasing sediment storage can be analyzed in an analogous manner.

7. The sediment washoff during each simulation interval is equal to the smaller of two values; the transport capacity of overland flow or the sediment available for transport from pervious or impervious surfaces in each land use. To indicate which condition is occurring, the user should output values for STCAP, the sediment transport capacity by surface runoff, using the DISPLY function of HSPF. These values can then be compared with the washoff values reported in the output for section SEDMNT of PERLND (DISPLY cannot currently output transport capacities for impervious land surfaces.) Generally, washoff will be at capacity during the beginning intervals of a significant storm event; this simulates the "first flush" effect observed in many nonpoint pollution studies. As the surface sediment storage is reduced, washoff will be limited by the sediment storage during the latter part of storm events. However, for very small events overland flow will be quite small and washoff can occur at capacity throughout. Also, on agricultural and construction areas washoff will likely occur at capacity for an extended period of time due to the large amount of sediment available for transport.

8. Using the information provided by displaying the values for STCAP, minor adjustments in JRER, JSER, and JEIM can be used to alter the

shape of the sediment graph for storm events. For pervious areas when available sediment is limiting, increasing JRER will tend to increase peak values and decrease low values in the sediment graph. Decreasing JRER will have the opposite effect tending to decrease the variability of simulated values. When sediment is not limiting, the JSER parameter will produce the same effect. Increasing JSER will increase variability while decreasing it will decrease variability.

For impervious areas, the JEIM parameter will produce the effects described above when sediment washoff from impervious areas is occurring at the transport capacity. All these parameters will also influence the overall sediment balance, but if parameter adjustments are minor, the impact should not be significant.

9. HSPF includes algorithms to represent scouring of the soil matrix as an additional component of the total sediment erosion. Since this process was not included in the ARM and NPS models, there is little experience upon which to base parameter values. The relevant parameters are KGER (coefficient) and JGER (exponent); the mathematical formulation is a power function of overland flow, identical to the transport capacity equation, but it is not limited by available particles since it is scouring the soil matrix. The parameters are analogous to those discussed above, and the scouring algorithm can be employed to increase sediment erosion on watersheds where scouring and gully formation is evident.

Sediment calibration should be performed on a single land use at a time, if possible, in order to correctly evaluate contributions from individual land uses.

Sediment Transport Calibration

While land surface sediment erosion is simulated in terms of total sediment, instream sediment transport (using section SEDTRN of RCHRES) is calculated based on the three component fractions of sediment (sand, silt, and clay). There are no calibration parameters involved in simulation of sand transport by the Colby or Toffaleti methods. If, however, sand transport is modeled as a power function of stream velocity (SANDFG=3), the user can control the process to a certain extent by adjusting the values for the coefficient (KSAND) and exponent (EXPSND) of the transport equation.

The successful simulation of cohesive sediments (silt and clay) is much more dependent on calibration. The three parameters used for calibration are the critical shear stress for deposition (TAUCD); critical shear stress for erosion (TAUCS); and the rate of erosion, or erodibility coefficient (M). Successful calibration of the instream sediment transport processes for cohesive sediments requires the following five steps:

1. Using the hydraulic calibration, identify a period of record which contains events which have a good fit between recorded and simulated flows. Sediment transport processes, and the sediment calibration must be based on an accurate hydraulic representation in order for the values derived for TAUCD, TAUCS, and M to be meaningful. The calibration period must contain significant runoff events in order to properly define the runoff/sediment washoff relationship at higher flows.

2. Use the HSPF DISPLAY function to output daily values for calculated shear stress, TAU. Identify the range of values for TAU which are characteristic of periods which exhibit significant suspension of sediment in the historical data.

3. Set values for the critical shear stress for erosion of silt and clay which bracket the period of increased suspended load. Proper selection of values for TAUCS should result in scour and suspension of cohesive materials during periods of increased flow and shear stress, but no erosion during periods when the historical record shows minimal suspended sediment.

4. By examining calculated values for TAU during low flow and less turbulent portions of the simulation record, select values for TAUCD for silt and clay which allow deposition only during appropriate periods.

5. Adjust the erodibility coefficient, M, to obtain the best overall correspondence between observed and simulated sediment loads for events with good hydraulic fit.

Sediment transport processes are strongly linked to hydraulic processes, and a good hydraulic calibration is a necessity for a good sediment simulation. In order to perform a meaningful instream sediment calibration, the erosion must also be reasonably accurate. In essence, the instream calibration is merely an adjustment of bed sediment, by deposition or scour, to make up the difference between edge-of-stream loadings and observed loadings at a point downstream.

PERLND Water Quality Calibration

Dissolved Gases. Calibration of dissolved gases simulation by PERLND (section PWTGAS) is limited to a few relatively simple adjustments.

1. Estimate all dissolved gas parameters and storages from the literature and all available information on the study area.
2. Depending on whether or not soil temperature is simulated, adjust soil temperature simulation results or input time series data to modify gas saturation values calculated for surface runoff.
3. If gas concentrations (or mass loadings) from the combined outflow from surface runoff, interflow and groundwater are not reasonable, adjust user-specified gas concentrations for interflow and groundwater until acceptable results are obtained.

General Quality Constituents. Calibration procedures for simulation of general quality constituents or pollutants (using section PQUAL) vary depending on whether constituents are modeled as sediment-associated or flow-associated.

Calibration of sediment-associated pollutants begins after a satisfactory calibration of sediment washoff has been completed. At this point adjustments in the pollutant potency factors (POTFW and POTFS) can be performed. Generally, monthly and annual pollutant loss will not be available, so the potency factors will be adjusted by comparing simulated and recorded pollutant concentrations, or mass removal, for selected storm events. For nonpoint pollution, mass removal in terms of pollutant mass per unit time (e.g., gm/min) is often more indicative of the washoff and scour mechanisms than instantaneous observed pollutant concentrations. However, the available data will often govern the type of comparison performed.

Storms that are well simulated for both flow and sediment should be used for calibrating the potency factors. The initial values of potency factors should be increased if pollutant graphs are uniformly low and decreased if the graphs are uniformly high. Monthly variations in potency factors can be used for finer adjustments of simulation in different seasons if sufficient evidence and information is available to indicate variations for the specific pollutant. However, individual storms should not be closely matched at the expense of the other storms in the season. Also, consistency between the sediment and pollutant simulation is important; if sediment is under-simulated then the pollutant should be under-simulated, and vice versa. Inconsistent simulations can indicate that sediment is not a transport mechanism for the particular pollutant or that the potency factors have been incorrectly applied. Also, if there is no similarity between the shapes of the recorded sediment and pollutant graphs, then pollutant transport is not directly related to sediment transport and no amount of adjustment will allow an effective simulation of that pollutant.

Calibration procedures for simulation of pollutants associated with overland flow are focused on the adjustment of three parameters: the pollutant accumulation rate (ACQOP); the maximum pollutant storage on the land surface (SQOLIM); and the parameter which relates runoff intensity to pollutant washoff (WSQOP). As was the case for sediment-associated constituents, calibration is performed by comparing simulated and recorded pollutant concentrations, or mass removal, for selected storm events. In making this comparison, the following issues should be considered:

1. If too much pollutant washoff is simulated for all storms, the value used for maximum storage (SQOLIM) is probably too high. Likewise, consistently low simulations of pollutant washoff indicate the value used for SQOLIM is too low.

2. If too much washoff is simulated for small storms, but not for large storms, the value assigned for the washoff rate parameter (WSQOP) may be too low.

3. If simulation results for storms following long periods without rain are good, but too much washoff is simulated for storms which occur in close sequence to earlier storms, the value used for the accumulation rate parameter (ACQOP) is probably too high and should be adjusted accordingly. Of course, the opposite is true if simulated values are low for storms of this type.

In most cases, proper adjustment of SQOLIM, WSQOP, and ACQOP allows a good representation of the washoff of flow-associated constituents. In study areas where pollutant movement is also associated with subsurface flows, the user may assign pollutant concentration values for both interflow and active groundwater. If this option is exercised, one should pay careful attention to the influence which these pollutant sources are having on simulated net pollutant outflows, particularly if observed instream pollutant data are being considered in the calibration process.

Pesticide Calibration. Ideally pesticide simulation should require little, if any, calibration since all the pesticide parameters represent characteristics that can be determined in laboratory experiments. However, inaccuracies in the pesticide algorithms, discrepancies between laboratory and field conditions, variability in measured laboratory values, or lack of pertinent laboratory values will usually require some adjustment or calibration of initial parameter values. Calibration should be done by comparing simulated values with measured field data. If no field data are available, data from watersheds under similar conditions and personal experience should be used to evaluate the simulated values.

The intent of pesticide calibration is to: (1) obtain the correct time distribution of the amount of pesticide in the soil following application by adjustment of the degradation parameters; (2) obtain the correct vertical distribution of pesticides in the various soil layers by adjusting the leaching factors; and (3) obtain the correct partitioning between solution and sediment-associated pesticide by adjusting the adsorption/desorption parameters. With this procedure in mind, the following steps and guidelines for pesticide calibration are recommended.

1. Estimate all pesticide and solute leaching parameters from the literature and all available information on the field site.

2. Adjust pesticide decay rates (primarily in surface and upper soil zones) to better reflect the observed soil core data.

3. Adjust solute leaching parameters (primarily surface and upper zone values) to better reflect the pesticide distribution between the surface and upper zones, as determined from the soil core data or calibration with a nonreactive tracer (e.g., chloride).

4. Adjust adsorption/desorption parameters as needed to obtain the proper distribution between solution and adsorbed forms.

5. Compare storm event pesticide losses in solution and adsorbed forms with observed data and make further parameter adjustments as discussed above.

Nutrient Calibration. Nutrient calibration begins with analysis and comparison of soil storages with observed soil nutrient data. Soil nutrient data obtained from sampling throughout the watershed for the period of calibration provides valuable information for the calibration of the nutrient parameters. If no soil nutrient data are available, calibration consists of merely estimating reasonable nutrient storages and comparing the recorded and simulated nutrient runoff results. However, all the simulation results (storages and runoff) should be evaluated for reasonableness based on personal experience and data from similar watersheds.

With or without observed data, the order of calibration is the same and is analogous to the pesticide calibration procedures.

Nutrient calibration involves the establishment of reasonable soil nutrient storages through adjustment of percolation parameters, plant uptake parameters, and reaction rates, followed by evaluation of nutrient runoff and refinement of pertinent parameters. The recommended order and steps in the procedure are:

1. Evaluate initial soil nutrient parameters from information available in the literature, and include fertilizer and rainfall sources of nutrients as input to the model.

2. Calibrate initial mineralization rates so that annual amounts of plant-available nutrients correspond to expected values.

3. Adjust leaching factors based on any data available for a tracer such as chloride.

4. Adjust plant uptake rates to develop the expected nutrient uptake distribution during the growing season and the estimated total uptake amount expected for the crop.

5. Adjust nutrient partition coefficients based on available core and runoff data.

6. Refine the leaching, uptake, and partition parameters based on observed runoff data and the expected sources of nutrient runoff, i.e., surface, interflow, groundwater.

As with pesticide calibration, some iteration of the steps is often required. Parameter values may need to be readjusted as later steps affect prior adjustments, but the order designated should help to minimize the number of iterations in the calibration procedure.

IMPLND Water Quality Calibration.

Procedures for calibrating the simulation of dissolved gases and general water quality constituents using the IMPLND module are the same as those outlined for calibrating land surface processes in PERLND; however, subsurface processes are not considered in IMPLND and hence are not a factor in calibration. (Refer to calibration guidelines for PWTGAS and PQUAL for assistance.)

RCHRES Water Quality Calibration

Water Temperature. Given the strong influence that water temperature has on biological and chemical reaction rates, it is important to obtain the most reasonable values for water temperature possible. If available meteorologic data and observed instream temperature data are adequate to perform temperature simulation and calibration, the modeler should use adjustments to four parameters: CFSAEX, KATRAD, KCOND, and KEVAP as a basis for calibration:

1. CFSAEX is the ratio of shortwave radiation incident to a reach to radiation incident at the recording station. If heavy vegetation or irregular topography shades a reach for all or part of the day, the value of this parameter can be lowered accordingly. Since shortwave radiation is the largest source of heat to the reach, adjustment of the value for CFSAEX is the most effective of all four water temperature calibration parameters.

2. The values for the other three parameters are physically based, and the default values for all three should be used for the first calibration run.

3. An increase in the value of the atmospheric longwave radiation coefficient (KATRAD) will tend to increase water temperature.

4. An increase in the value of the conductive - convective heat transport coefficient (KCOND) will increase heat transfer between water and the atmosphere. Consequently, simulated water temperature may either increase or decrease

depending on the relative temperatures of water and air.

5. Increasing the value of the evaporation coefficient (KEVAP) will tend to decrease simulated water temperature.

The user should note that in situations where point loadings contribute a significant volume of water to the reach system, the water temperature values assigned to the point loading may become the dominant factor in water temperature simulation. If reasonable adjustments to the four calibration parameters cannot produce an acceptable calibration, input data for point loads or meteorology are most likely unrepresentative of the study reaches and should be re-examined.

General Quality Constituents (GQUAL). The specific procedures used to calibrate the simulation of a generalized quality constituent, or GQUAL, depend on the relative adsorption characteristics of the compound and the availability of laboratory data to characterize the various decay processes (i.e., hydrolysis, oxidation, photolysis, volatilization, biodegradation) which can be modeled. The key parameters are the partition coefficients, the process-specific or lumped decay rates, and the adsorption/desorption transfer rates for approaching equilibrium conditions.

If a GQUAL adsorbs to and hence is transported by sediment, the partition coefficients (Section 4.4(3).7.13, Part F of the User's Manual) for the substance are perhaps the most important calibration parameters, since they will establish the distribution of the GQUAL between the solution phase, suspended sediment, and bed sediment. Except for tracers, such as chlorides and other non-reactive compounds, most chemicals and especially organic chemicals will undergo adsorption to sediment particles, particularly silt and clay fractions, and associated organic matter.

As a first step, laboratory derived values for partition coefficients for the specific chemical and sediment combination should be used, and their effects on simulation results should be assessed. Octanol-water (Kow) and organic carbon (Koc) partition coefficients can be used to estimate the relevant coefficients for the sand, silt, and clay fractions of both suspended and bed sediments, based on estimates of their organic matter or organic carbon content. The user should note that a compound will usually adsorb differently to suspended and bed sediments, requiring different values of partition coefficients.

If field data (i.e., instream and/or bed chemical concentrations) indicate that the laboratory values are not appropriate, the estimated partition coefficients can be adjusted accordingly. In making adjustments, one should remember that the simulation of sediment-associated constituents is heavily influenced by sediment simulation and that adjustment of the partition coefficient values should not be used as a means of correcting deficiencies introduced by an inaccurate sediment simulation. Decay rates are specified separately for the soluble component, the adsorbed component on suspended sediments, and the adsorbed component on the bed sediments. The process-specific rates are available only for the soluble component; the adsorbed components use a single lumped decay rate for each size fraction (i.e., sand, silt, clay). Generally, the same decay rate is used for all size fractions, unless data indicates otherwise, but different rates are expected for the suspended and bed sediments.

For most constituents which are modeled with module section GQUAL, detailed laboratory data needed to evaluate parameters for specific degradation processes are not generally available. Even if relevant data exists, large variations in degradation rates can occur in the field. For this reason, it is a common practice currently to lump the effects of all forms of degradation into a general decay parameter (Section 4.4(3).7.11, Part F of the User's Manual) and treat it as a calibration parameter.

Current efforts to develop laboratory protocols for measuring process rate parameters and prepare data bases for contemporary compounds should help to provide a better basis for estimating process-specific rate parameters in the future. Since environmental conditions such as water temperature, pH, cloud cover, and others, affect the rate at which components of the total degradation occur, estimation of a general degradation rate is always somewhat inaccurate and adjustment through calibration may be justified, if possible. In any case, the user should be cognizant of the primary decay mechanisms of the compound so that the impact of including or excluding effects of environmental conditions can be assessed.

The adsorption/desorption transfer rate parameters represent the rate at which the system approaches equilibrium adsorption conditions between the soluble and suspended and bed sediments. This concept was included to allow either an equilibrium or kinetic approach to adsorption since equilibrium partitioning conditions are not often achieved instantaneously in natural aquatic systems. Very little information is available on which to evaluate these rate parameters. Sensitivity studies conducted as part of our

Four Mile Creek application indicate the following:

a. Large partition coefficients and sediment concentrations increase the effect of the transfer rate on the total chemical load because a greater fraction of the load is transported with the sediment.

b. If the majority of the chemical load is in solution, the primary impact of the transfer rate is to control the amount of chemical adsorbed to the bed and subsequently released to the water column in the time period following peak concentrations. This was observed in Four Mile Creek by measurable pesticide concentrations for several days following a storm event.

c. Equilibrium conditions can be approximated (i.e., instanteously in each time interval) by setting the transfer rate equal to three times the number of simulation time intervals in a day. Thus, with an hourly time step, a transfer rate of 72 (3x24) per day would achieve 95% of equilibrium conditions within one time interval. Alternatively, a value of 24 per day (assuming an hourly time step) would achieve 95% of equilibrium within three time steps, since first-order kinetics are assumed; this is sufficiently fast as to practically represent equilibrium adsorption conditions in most aquatic systems.

d. In our Four Mile Creek study, we derived through calibration transfer rates of 8.0 and 0.03 for the suspended and bed sediments, respectively. Logically, the rate for the suspended sediments in the water column should be substantially greater than the bed transfer rate due to instream mixing and turbulence. The bed transfer rate also depends, to some extent, on the assumed bed depth and associated sediment mass available to adsorb chemicals; a one-foot depth was assumed in our Four Mile Creek study.

Detailed Simulation of Selected Constituents Involved in Biochemical Transformations (RQUAL). As the generalized calibration procedures outlined in Section 7.1 indicate, the calibration of RQUAL can be quite complicated and time-consuming, depending on the number of constituents and processes which are simulated. In fact, adjustment of RQUAL simulation results to more closely duplicate observed values is not always achieved solely by calibration. In some cases, simulation of additional constituents and/or processes may allow improvements to simulation results which cannot be obtained by adjustment of parameter values. For example, simulation of plankton may be necessary in order to duplicate observed seasonal fluctuations in nutrient concentrations, or volatilization may need to be modeled in order to reproduce the observed nitrogen mass balance for a lake. Thus, while the user is allowed to model nutrients without consideration of plankton and/or volatilization, it may not be possible to obtain a good fit between simulated and observed nutrient values in cases where these factors are important but are not modeled. Module sections GQUAL and RQUAL contain many user options for simulating or not simulating various constituents and processes. Simulation results are equally dependent on the simulation of all important constituents/processes and on development of realistic parameter values.

Calibration of RQUAL is complicated by two factors. First, the interrelationships of the various constituents result in changes in simulated concentrations for numerous constituents by adjustment of a parameter value specific to only one constituent. For example, if one increases the value for the algal respiration rate parameter in order to reduce simulated plankton populations, the modification will also result in increased values for nutrients and inorganic carbon and a decreased value for dissolved oxygen. Thus, the final calibration of any one constituent in RQUAL cannot be completed until all adjustments have been made to associated constituents. The calibration of RQUAL is complete when the best overall fit to data is achieved for all constituents which are simulated.

The second factor which complicates the calibration of RQUAL is the wide range of values which have been reported for the model parameters. The variability of literature values for many of these parameters results from the complexity of the physical, chemical, and biological factors which influence the ultimate biochemistry of each individual stream or lake. Quite often it is difficult for the model user to know whether or not the values assigned to calibration parameters are reasonable for the study area, even if the values do result in a good simulation.

Given the potential complexity of RQUAL simulation, as well as the flexibility allowed in constituents/processes simulated, it is not possible to describe a detailed calibration procedure. Nonetheless, the parameters identified below are generally considered to be the most useful for calibration of the various constituents considered in RQUAL:

oxygen	- BENOD	benthal oxygen demand rate
BOD	- BRBOD	benthal release rate for BOD
	KBOD20	decay rate of BOD
nutrients	- BRCON(I)	benthal release rates for nitrate and orthophosphorus
	KNH320	oxidation rate of ammonia
	KNO220	oxidation rate of nitrite
	DEBAC	fraction of denitrifying bacteria
algae	- CFSAEX	correction factor for surface area exposed to sunlight
	LITSED	light extinction factor to account for suspended sediment
	EXTB	base extinction coefficient for light
	MARGR	maximal unit algal growth rate
	ALR20	algal unit respiration rate
	ALDH	high algal death rate
	ALDL	low algal death rate
zooplankton	- MZOEAT	maximum zooplankton unit ingestion rate
	ZFIL20	zooplankton filtering rate
	ZRES20	zooplankton unit respiration rate
	ZD	zooplankton unit death rate
pH/carbon	- BRCO2	benthal release rate for CO2

7.3 How Much Calibration?

A common question that is asked by model users concerns the extent of calibration or parameter adjustment necessary before one can say that the model is "calibrated" to the test watershed. Obviously this depends to some extent on how well the initial parameter values are estimated. But beyond that, the question is really "How close should the simulated and recorded values be before calibration can be terminated?" The answer to this question depends on a number of factors including the extent and reliability of the available data, the problems analyzed vs. the model capabilites, and the allowable time and costs for calibration.

Data Problems. The available data are often the most severe limitation on calibration especially for water quality variables. A common mistake by model users is to accept the observed data as being absolutely accurate. In fact, any measurement obtained under field or natural conditions will usually contain at least a 5 to 10 percent variation from the actual or true value. Moreover, instantaneous or short time interval measurements commonly show variations of 10 to 20 percent and greater for flow or concentration values. Usually annual volumes and total loss measurements are the most accurate except when a persistent bias exists in the measurement technique or calculation method.

The assumption of uniform areal precipitation is a major source of error with direct effects on the simulation since precipitation is the driving force of HSPF. Precipitation is rarely uniform and is highly nonuniform in thunderstorm prone regions of the country. This nonuniformity makes simulation of thunderstorms difficult since the actual rainfall is unknown if the recording gage does not adequately represent the rainfall pattern.

The user should be aware of the measurement techniques and the resulting confidence limits of the observed values for both the input meteorologic data and the runoff or soil calibration data. Simulated values within the confidence limits of the observed calibration data cannot be improved upon; this signals a reasonable end to calibration. However, this is not an absolute criterion since a good overall calibration can include simulated individual storm events or instantaneous values with larger variations than the accepted confidence limits. In such cases, analysis of the discrepancies and personal judgment must be called upon to decide if calibration is sufficient.

Problems Analyzed vs. Model Capabilities. Another source of frustration in model calibration is the attempt to calibrate a model for conditions or processes that the model cannot adequately represent. For example, at present HSPF cannot fully represent the effects of specific tillage operations on runoff and soil moisture. While the Special Actions Block can be used to approximate changes in soil properties related to tillage, additional research is needed to determine how these changes can be simulated deterministically. Runoff for storms occurring soon after a tillage operation may not be well simulated, but this effect decreases with the time since tillage. Calibration of parameters to better simulate such events will produce a biased set of hydrologic parameters, and subsequent simulation results will not be realistic.

To avoid such problems, the user should have a basic understanding of the processes that are occurring on the watershed, the processes simulated by HSPF, and their method of representation in the model. Study of HSPF algorithms provides an additional benefit since the user will acquire a better understanding of the role of model parameters and the impact of parameter adjustments. Calibration can be expedited with this knowledge, and with the realization that certain processes affecting the observed data are not represented in the model. Parameter adjustments to circumvent such model limitations are both inappropriate and futile.

Guidelines. In many applications of HSPF, the time and costs budgeted to calibration will determine the level of effort expended. Calibration is a critical step in any model application and may require 30 to 50 percent of the total project resources. Its importance cannot be understated. The arguments provided above should not be used to justify reducing the time and costs required for a reasonable calibration. However, our experience has shown that many diligent users will often spend too much time on calibration due to insufficient observed data, ignorance of the accuracy of the data, and misconceptions of model capabilities and parameter sensitivities.

The agreement between simulated and recorded values required for an adequate calibration is highly dependent on the specific watershed, data conditions, and problems analyzed. Very little quantitative information exists to provide guidelines for evaluating a calibration. However, from our experience in applying HSPF and related models and within the framework of the considerations discussed above, the following general guidelines for characterizing a calibration are provided to assist potential model users:

Difference Between Simulated and Recorded Values (percent)

	Calibration Results		
	Very Good	Good	Fair
Hydrology/Hydraulics	<10	10-15	15-25
Sediment	<15	15-25	25-35
Water Quality	<20	20-30	30-40

The above percent variations largely apply to annual and monthly values. Individual events may show considerably larger variation for many reasons with little impact on the overall calibration. These values should be used only as approximate guidelines. The user should attempt to obtain the best calibration possible within the limitations of the available data, the model capabilities, and the allowable budget.

7.4 Verification

Model verification is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions which can affect model results. While there are several approaches to verifying a model, perhaps the most effective procedure is to use only a portion of the available record of observed values for calibration; once the final parameter values are developed through calibration, simulation is performed for the remaining period of observed values and goodness-of-fit between recorded and simulated values is reassessed. This type of split-sample calibration/verification is highly recommended. However, in data-poor situations there is a real question as to whether to calibrate on half the data and verify on the other half, or obtain the best calibration on all the observed data. In any case, credibility is based on the ability of a single set of parameters to represent the entire range of observed data. Overall model credibility can be enhanced if the model is applied by independent users, in a variety of watersheds, and for a range of events with different magnitudes. If a single parameter set can reasonably represent a wide range of events, then this is a form of verification.

Quantitative measures of verification are needed and model reports should always include comparison of simulated and observed data. This should be done for runoff volumes, pollutant loads, hydrographs and pollutographs. Correlations of point-to-point comparisons may not be valid, due to time shifts. For nonpoint source pollution, mass loads are usually more appropriate for comparison than concentrations.

SECTION 8

ANALYSIS OF ALTERNATIVE CONDITIONS

The analysis of proposed or projected alternative conditions for a watershed or water system will be the most critical step in many HSPF applications. The results of this step will often provide direct input to the decision-making process by supplying the necessary system response information to evaluate and compare alternatives. Unfortunately, coming at the end of the model application process, this analysis step is often plagued by short time schedules, inadequate resources, and insufficient data/information for an indepth investigation. The model user must be aware of these potential pitfalls in order to preserve sufficient project resources for this final task of analyzing proposed alternatives. In effect, the ultimate utility of the HSPF application will often depend on the successful completion of this analysis, as measured by the ability of the model to represent alternative conditions and provide sufficient data for a valid comparison.

Because of the comprehensive scope of HSPF, once it has been applied (i.e., calibrated/verified) to a watershed system it can be subsequently used to analyze a variety of alternatives and associated impacts. Water projects related to flood control, storm drainage, urban and agricultural best management practices, water supply, hydropower, municipal and industrial waste treatment, etc. can be analyzed within a comprehensive watershed management approach. This section discusses the basic philosophy underlying the use of HSPF for analysis of alternatives, enumerates the various steps involved in this process, provides guidance in analyzing selected alternatives, and describes related examples drawn from past experience with HSPF and/or predecessor models.

8.1 Philosophy Underlying Comparison of Alternatives

The philosophy underlying the use of HSPF for analyzing various alternatives is a basic component of the concepts and assumptions of the continuous simulation approach. The calibrated/verified model is used as a tool to project changes in system response resulting from a proposed alternative; this alternative is represented in HSPF by adjustments (changes) to model input, parameters, and/or system representation (e.g., interconnection of PLSs and stream reaches). During the calibration/verification steps, the model results are compared with observed data for selected time periods; whereas, in the analysis of alternatives the model results for a specific alternative are compared to model results produced by appropriate base conditions. In this way the relative changes in system response associated with a proposed alternative can be identified and analyzed.

Two key aspects of analyzing alternatives involve the methods and procedures for characterizing both the system (base condition and alternatives) and the system response. A common misconception of potential users of continuous simulation models is that the model is designed to duplicate observed data on the watershed (i.e., system) for the extended simulation periods of 10 years or more. In reality, the observed data reflects dynamic changes occurring on the watershed such as land use changes, channel modifications, water use patterns, etc., whereas the model describes what would have been observed under static (constant) watershed conditions. For this reason calibration and verification time periods are specifically chosen to be long enough to cover a range of hydrometeorologic conditions (to satisfy calibration/verification needs), but short enough to limit physical changes that could significantly impact the system response (to satisfy the static conditions assumption).

In effect, a Monte Carlo type approach is employed where the input meteorologic data is the driving function used to generate a corresponding output time series under constant watershed conditions; the output time series is then analyzed to characterize the watershed response under the defined conditions. This characterization can be based on a variety of numeric measures, such as mean, maximum, and/or minimum values of flow, reservoir volumes, pollutant concentrations, and/or loads for monthly, seasonal or annual periods.

Alternately, a frequency-duration analysis can be performed for any output time series to determine the 'percent of time' that hourly, multi-hourly, or daily values exceed (or are less than) specific target values. Frequency analysis is generally preferred since it provides a more rigorous characterization of the system response over the entire range of dynamic watershed conditions. Moreover, frequency information provides a means of assessing flood damages, water quality impacts, fish toxicity conditions, etc. associated with extreme values of flow and pollutant concentrations.

As described in Section 4, HSPF can provide all the numeric and statistical measures noted above. A consistent set of measures must be chosen and generated for both the base condition and each alternative in order to provide a valid basis for comparison.

8.2 Steps in the Analysis Process

Prior to analysis of alternatives, the calibration/verification process must proceed to the state where model results are sufficient to demonstrate that the model provides a realistic and credible representation of the system response. At this point, the proposed alternatives can be analyzed by the following procedures:

1. Define appropriate base conditions to which alternatives will be compared. This may be the calibrated condition, or some modification of it.

2. Define the simulation time period, output time series, and numeric/statistical measures to be used to characterize and compare the base condition with proposed alternatives.

3. Simulate base conditions for the simulation period, and generate the selected time series and numeric/statistical measures.

4. Define alternatives to be analyzed. Each alternative should provide a meaningful and realistic difference from the base condition.

5. Define and incorporate all effects of the proposed alternative on model parameters, inputs, and/or system representation.

6. Perform simulation runs for each proposed alternative for the identical time period as the base condition, and generate identical time series and numeric/statistical measures. **Make sure that the only differences between the base and alternative runs are due to the alternative being analyzed**.

7. Compare model output and numeric/statistical measures of the base and alternative model runs. The model user should be able to explain and justify the differences; if the differences are counter-intuitive, check parameters and model output for possible errors.

Although each of the above steps are important, it is clear that the critical step in the analysis is Step # 5, defining the effects of the proposed alternative in terms of specific changes in model inputs, parameters, and/or system representation (e.g., interconnection of PLSs and stream reaches). Due to the wide range of alternatives that can be analyzed with HSPF, the process of determining required changes is best shown by example.

8.3 Examples of Analyzing Alternatives with HSPF

Table 8.1 presents a summary of how various water project alternatives can be represented with HSPF and lists the associated changes in the input sequence. As noted above, simulation of alternatives will require adjustments to model input, parameters, and/or system representation. Generally, changes to model input and system representation will be the easiest to specify and provide the greatest reliability in the resulting simulation. For example, model input changes will include modifications to point load, flow, and/or rainfall files in the TSS to represent alternatives such as municipal/industrial waste treatment levels, instream aeration, flow augmentation, rainfall augmentation, wasteload allocation, etc. System representation can be changed to analyze land use changes, reservoir operations, reservoir site alternatives, stream modifications, etc. Although it is often stated that modeling should be used only to analyze differences between alternatives, a well calibrated/verified model can provide absolute values with an acceptable degree of reliability. This is especially true if the relatively, straight-forward changes in model input and system configuration provide a reasonably accurate representation of alternatives being analyzed.

However, the same degree of absolute accuracy cannot be attributed to model parameter adjustments used to evaluate alternatives such as stormwater drainage plans, urban and agricultural BMPs, and land/soil disruptions from construction, mining, silviculture, waste disposal, etc. The impact of these types of activities on certain parameters, such as infiltration, soil erodibility, soil moisture capacity, etc. is not well defined; model results should be viewed primarily as describing the relative differences between alternatives based on current best estimates of the relative change in certain parameter values.

Specific examples of projects where HSPF and/or predecessor models have been used to analyze alternatives are described below:

Table 8.1 Selected Alternatives, Associated HSPF Assumptions, and Suggested Input Modifications

ALTERNATIVES	MODEL REPRESENTATION	SUGGESTED HSPF INPUT MODIFICATIONS
Municipal and industrial waste treatment	Changes in point load discharges to stream	Modify point load input files in TSS using MFACT in EXT SOURCES or GENER options
Instream aeration	Point load of oxygen to stream	Develop point load oxygen file and input through EXT SOURCES block
Land use changes	Change in relative fractions of existing land use categories	Change multiplication factors in NETWORK block entries connecting PERLND, IMPLND, and RCHRES operations
Reservoir operations analysis (e.g. water supply, hydropower, flood control, water quality)	Change in operating rule curves and outflow demands for existing reservoirs	Modify FTABLES to reflect new operating procedures; adjust time varying outflow demand in TSS; may require linkage to multi-layer lake model through MUTSIN/PLTGEN modules
Reservoir site investigations	Replace existing stream reach with a proposed reservoir	Modify OPN SEQUENCE, RCHRES, and NETWORK blocks to insert new reservoir and add FTABLE for expected operating procedures; see reservoir operations analysis
Flow augmentation and/or diversions	Changes in inflows and/or outflows to or from specific stream/reservoir reaches	Add or modify time series of flows or outflow demands through the NETWORK, RCHRES and/or FTABLE Blocks
Rainfall augmentation	Clearly defined (expected) increases in rainfall volumes, duration, intensity	Modify input rainfall records using GENER options and/or MFACT in EXT SOURCES block
Wasteload allocation	Distribute allowable waste loading among existing/expected dischargers	Modify point load input files in TSS to meet stream water quality standards
Stream modifications (e.g. channelization, levees)	Modified flow characteristics in specific stream sections	Modify RCHRES block and associated FTABLES to reflect changes
Stormwater drainage and management	Defined components of proposed plan, e.g. storage/treatment, street sweeping	Modify appropriate PERLND parameters and/or RCHRES system as needed to represent plan; may require GENER operations and/or linkage with an urban storage/treatment model
Urban and/or agricultural best management practices (BMPs)	Defined components of each BMP and difference from base condition	Modify appropriate PERLND parameters and/or configuration of land segments to represent each BMP
Land/soil disruptions (e.g. construction, mining, silviculture, waste disposal)	Defined conditions resulting from specific type of disruption	Modify appropriate PERLND parameters to represent 'disrupted' or changed condition; will often require separate pervious land segment with modified parameters

Iowa River Basin Study

The Iowa River Basin study (discussed throughout this manual) was designed to evaluate the utility of HSPF as a planning tool to analyze the runoff, pollutant loading, and instream water quality changes resulting from proposed agricultural BMPs. Following the preliminary hydrology and sediment calibration, and pesticide and nutrient simulation for the entire basin, the BMP analyses were performed.

Conventional agricultural practices for Iowa provided the base conditions to which a proposed BMP scenario i.e., a combination of selected, compatible practices, was compared. The definition of conventional practices was as follows:

DEFINITION OF CONVENTIONAL AGRICULTURAL PRACTICES FOR IOWA WATERSHEDS

> Conventional agricultural practices for Iowa are assumed to include continuous row-cropping (no rotation) and moldboard plowing followed by secondary tillage at least once to smooth and pulverize the soil for planting, with cultivation when and where appropriate. Cropping and tillage operations are assumed to be straight row and usually parallel to field borders regardless of slope direction. Fertilizer application and moldboard plowing are assumed to be done in the fall, with disking and pesticide application in the spring prior to planting. In all cases with conventional tillage, the soil surface is free from residues for a period of time. One or two cultivation operations may be performed as needed during the early growing season (Donigian et al., 1983a).

The primary components include moldboard plowing and secondary tillage for seedbed preparation, one or two (chosen for simulation) cultivation operations during the early growing season, and crop residue removal following harvest in the fall.

The BMP scenario chosen for simulation included conservation tillage plus the use of contouring; the assumptions used in representing this scenario are listed in Table 8.2. These changes are based on studies performed as part of the Iowa Field Evaluation Program by Donigian, et al., (1983a) to assess the effects of a variety of candidate BMPs on HSPF model parameters. Specific parameter values for base and BMP conditions are included in the Iowa River Study report.

As noted in Table 8.2, the primary components of our BMP scenario were (1) a shift from moldboard plowing to chisel plowing and field cultivation as primary tillage, (2) one summer cultivation for weed control in place of two cultivations under base conditions, and (3) allowing crop residues to remain on the field following harvest. These components were modeled by increasing parameter values for soil moisture retenti... (UZSN), rainfall interception, surface roughness (Manning's n), and land cover; and decreasing the sediment fines produced by tillage. The infiltration parameter was not changed, under the assumption that the primary tillage operations have similar effects on the infiltration process. Also, there was no change in chemical parameters, soil bulk density, soil temperature, or chemical application amounts, although fall fertilizer application was replaced by increasing the spring and summer applications.

Using these assumptions and associated changes in parameter values, the resulting comparison of this BMP scenario and the previously simulated base conditions is shown in Tables 8.3 and 8.4. Table 8.3 presents a detailed comparison of the edge-of-stream loadings for the BMP and base conditions while Table 8.4 lists the resulting basin-wide loadings measured at Marengo, Iowa. The other/pasture land use category shows no effects since only corn and soybean cropland was affected under this BMP scenario.

Land Surface Simulation. Over the five year simulation period, annual runoff reductions from soybean and corn cropland were in the range of 4% to 17% with the larger reductions generally observed for corn. Groundwater outflow, the largest contributor to streamflow, shows the smallest effect (average reduction of 4.2%) from the BMP while surface runoff is decreased significantly (average reduction of 30% for soybeans and 26% for corn). As a consequence, sediment losses which come entirely from the surface were also reduced dramatically with soybean and corn reductions ranging from 45% to 69% (average 52%) and 33% to 73% (average 47%), respectively. In addition, BMP effects on erosion were much more pronounced than the resulting loading at Marengo since most of the sediment loading at Marengo resulted from channel scour processes rather than from land surface erosion. Solution alachlor edge-of-stream loading reductions were in the range of 4% to 42% with slightly greater reductions occurring on soybeans than corn; the average decrease for soybeans was 33%, and 19% for corn.

Nutrient simulation for both base conditions and the BMP was also performed for the entire five year simulation period. As shown in Table 8.3, total annual nitrate nitrogen reductions ranged from 3% to 10% for soybeans and 5% to 54%

for corn. Ammonia nitrogen was reduced 23% to 35% for soybeans and 18% to 82% for corn. The nitrate reductions were lowest in the first year of the simulation period since we assumed the same initial storages in the soil for both the base conditions and the BMP. Lower nitrate and higher ammonia storages in the first year of the BMP simulation

TABLE 8.2 SELECTED BMP SCENARIO FOR SIMULATION ON THE IOWA RIVER BASIN

CONSERVATION TILLAGE PLUS CONTOURING

1. Chisel plowing replaces fall moldboard plowing on corn residue
2. Field cultivation replaces spring plowing and disking on soybean residue
3. No change in infiltration parameter
4. Residues remain after harvest, with the following reductions by tillage and decay:

Moldboard	90%
Chisel	35%
Light disk	30%
Field cultivation	30%
Winter decay	
Soybeans	30%
Corn	10%

5. Reduction in sediment fines from tillage: 50 - 70%
6. UZSN increases due to contouring and less seedbed preparation
7. One summer cultivation replaces two cultivations under base conditions
8. Rainfall interception, surface roughness (Manning's n), and land cover increase due to residues and less tillage
9. No change in chemical application amounts, but fall nitrogen fertilizer application moved to spring and summer. Incorporation distribution as follows:

	Surface	Upper
Moldboard	0%	100%
Chisel	50%	50%
Disking	20%	80%
NH3 Injection	0%	100%
Cultivation	40%	60%

10. No change in chemical (pesticide or nutrient) parameters, bulk density, or soil temperature.

would have been more consistent with the storages calculated during the rest of the period. In fact, the initial nitrate nitrogen storage was high enough to preclude a significant reduction by the BMP scenario in 1974.

The effects of the BMP scenario upon surface nutrient processes occurring on the land surface are relatively small since the primary effect is to reduce surface runoff and not to affect the plant growth and other biological/chemical

Table 8.3. Comparison of Edge-of-Stream Loadings for Base Conditions and BMP Simulations in the Iowa River Basin

	SOYBEANS			CORN			OTHER/PASTURE
	BASE	BMP	% DIFF	BASE	BMP	% DIFF	BASE/BMP
RUNOFF (mm)							
1974	287.8	269.1	-6.5	311.9	285.7	-8.3	361.1
1975	208.1	198.7	-4.3	221.7	204.7	-7.6	252.0
1976	124.5	113.4	-8.9	133.8	114.2	-15.	156.7
1977	81.2	73.8	-9.1	87.9	72.9	-17.	121.0
1978	331.4	313.1	-5.5	342.8	320.1	-6.6	370.7
Avarage S *	21.8	15.3	-30.	26.9	19.9	-26.	10.7
I *	29.0	24.7	-15.	33.9	29.2	-14.	27.9
G *	156.0	154.0	-1.3	159.0	150.0	-5.7	214.0
T *	207.0	194.0	-6.3	220.0	200.0	-10.	252.0
SEDIMENT (tonnes/ha)							
1974	0.616	0.340	-45.	0.899	0.600	-33.	0.032
1975	0.224	0.097	-57.	0.375	0.197	-47.	0.023
1976	0.062	0.019	-69.	0.135	0.036	-73.	0.007
1977	0.018	0.009	-47.	0.028	0.015	-48.	0.002
1978	2.946	1.381	-53.	2.665	1.322	-50.	0.423
Average	0.773	0.369	-52.	0.820	0.434	-47.	0.107
ALACHLOR (kg/ha)							
1974	0.0905	0.0630	-30.	0.185	0.150	-19.	0.0
1975	0.0518	0.0302	-42.	0.0103	0.0081	-21.	0.0
1976	0.0102	0.0066	-35.	0.00697	0.00539	-23.	0.0
1977	0.00196	0.00183	-4.5	0.00132	0.00125	-5.6	0.0
1978	0.0764	0.0524	-31.	0.0380	0.0305	-20.	0.0
Average	0.0462	0.0308	-33.	0.0483	0.0390	-19.	0.0
NITRATE (kg/ha)							
1974	23.32	22.60	-3.1	51.80	49.38	-4.7	7.16
1975	9.18	8.66	-5.7	25.27	13.59	-46.	4.10
1976	6.69	6.06	-9.4	15.25	8.36	-45.	2.92
1977	4.12	3.68	-10.	6.91	3.17	-54.	2.53
1978	11.57	11.18	-3.4	29.46	17.93	-39.	7.16
Average S *	0.0129	0.0091	-29.	0.193	0.180	-6.7	0.0080
I *	1.14	0.975	-14.	7.69	6.10	-21.	0.349
G *	9.82	9.45	-3.8	15.5	12.21	-21.	3.92
T *	11.0	10.44	-5.1	23.4	18.49	-21.	4.77

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Table 8.3. continued

	SOYBEANS			CORN			OTHER/PASTURE
	BASE	BMP	% DIFF	BASE	BMP	% DIFF	BASE/BMP
AMMONIA (kg/ha)							
1974	0.719	0.551	-23.	3.12	2.23	-28.	0.772
1975	0.420	0.296	-29.	2.95	1.90	-35.	0.516
1976	0.634	0.409	-35.	2.45	0.641	-74.	0.521
1977	0.217	0.141	-35.	1.29	0.238	-82.	0.282
1978	0.807	0.587	-27.	5.28	4.34	-18.	0.976
Average S	0.0861	0.0637	-26.	0.297	0.773	+160.	0.0528
I	0.422	0.283	-36.	2.65	1.03	-61.	0.446
G	0.0500	0.0488	-2.4	0.0578	0.0479	-17.	0.114
T	0.559	0.397	-29.	3.02	1.87	-38.	0.613
MINERALIZATION (kg/ha)							
1974	51.3	51.0	-0.5	47.1	46.4	-1.3	38.7
1975	56.0	55.8	-0.3	51.0	50.5	-1.1	38.3
1976	56.3	56.1	-0.3	51.0	50.5	-1.0	37.6
1977	56.4	56.3	-0.2	51.1	50.7	-0.9	38.3
1978	56.3	56.9	-0.7	51.9	51.3	-1.3	38.5
Average	55.3	55.2	-0.2	50.4	49.9	-1.0	38.3
DENITRIFICATION (kg/ha)							
1974	8.23	8.28	+0.7	17.3	18.5	+6.9	2.46
1975	4.91	4.86	-0.9	14.2	12.4	-13.	2.26
1976	5.26	5.16	-1.9	13.7	12.2	-11.	2.17
1977	6.14	5.98	-2.6	13.6	12.2	-10.	2.82
1978	5.80	5.78	-0.4	14.3	12.6	-11.	3.11
Average	6.1	6.01	-1.6	14.6	13.6	-6.8	2.6
PLANT UPTAKE (kg/ha)							
1974	48.1	49.6	+3.1	147.8	177.6	+2.0	25.9
1975	34.4	35.8	+3.8	138.6	153.0	+10.	25.5
1976	37.7	38.4	+1.8	148.5	159.2	+7.	25.8
1977	55.0	54.4	-1.1	186.5	190.4	+2.	35.7
1978	39.7	40.7	+2.3	141.2	156.9	+11.	32.1
Average	43.0	43.8	+1.9	152.0	167.4	+10.	29.0

* S = Surface Outflow
I = Interflow Outflow
G = Groundwater Outflow
T = Total Outflow

processes occurring in the soil. In addition, the large storage of nutrients generally present on the land precludes any significant change in the nutrient processes due to a relatively small change in runoff. Consequently, the plant uptake, denitrification, and mineralization are not significantly changed under the BMP scenario.

Instream Simulation. Table 8.4 shows the effects of the BMP scenario on the runoff and water quality of the Iowa River

TABLE 8.4 COMPARISON OF LOADINGS IN THE IOWA RIVER AT MARENGO FOR BASE CONDITIONS AND BMP SIMULATIONS

		BASE	BMP	% DIFFERENCE
RUNOFF (mm)	1974	183.0	170.0	-7.1
	1975	124.0	116.0	-6.4
	1976	80.0	73.9	-7.6
	1977	47.8	42.4	-11.3
	1978	299.0	280.0	-6.4
	Average	147.0	136.0	-7.5
SEDIMENT (tonnes/ha)	1974	3.91	2.62	-33.0
	1975	0.88	0.47	-47.0
	1976	0.56	0.12	-79.0
	1977	0.019	0.012	-37.0
	1978	5.69	5.49	-3.5
	Average	2.21	1.74	-21.0
SOLN. ALACHLOR (kg/ha)	1974	0.0278	0.0219	-21.0
	1975	0.0025	0.0017	-35.0
	1976	0.0008	0.0004	-50.0
	1977	0.00	0.00	-
	1978	0.0068	0.0048	-29.0
	Average	0.0076	0.0058	-24.0
SED. ALACHLOR (kg/ha)	1974	0.0032	0.0020	-38.0
	1975	0.0002	0.0001	-50.0
	1976	0.00	0.00	-
	1977	0.00	0.00	-
	1978	0.0007	0.0004	-43.0
	Average	0.0008	0.0005	-38.0
NITRATE N (kg/ha)	1974	31.0	29.8	-3.9
	1975	14.9	9.5	-36.0
	1976	9.5	6.2	-35.0
	1977	4.9	3.0	-39.0
	1978	18.5	13.1	-29.0
	Average	15.8	12.3	-22.0
AMMONIA N (kg/ha)	1974	0.48	0.41	-15.0
	1975	0.57	0.30	-47.0
	1976	0.53	0.20	-62.0
	1977	0.37	0.09	-76.0
	1978	0.91	0.46	-49.0
	Average	0.57	0.29	-49.0

measured at Marengo, Iowa. Over the five year simulation period, total annual runoff reductions at Marengo were in the range of 7% to 11% with an overall average of 7.5% reduction. Annual sediment loss reductions were generally higher varying from 4% to 79% reduction with an overall average of 21% reduction over the simulation period. These sediment loss reductions are somewhat less than what might be expected; however, as discussed above, a significant portion of the total sediment loss is derived from the channel system itself which would not be significantly affected by the BMPs. Also, the 4% reduction in 1978 biased the average; the average reduction in 1974 to 1977 was 49%. Solution alachlor at Marengo was reduced from 0% to 50% with an average of 24% reduction over the simulation period; sediment alachlor was also reduced from 0% to 50%, averaging 37.5% over the period. The 0% reduction in alachlor occurred in 1976 and 1977, the years of extreme drought in central Iowa.

The instream nutrient results are also presented in Table 8.4 as annual nitrate and ammonia loadings at Marengo. The nitrate nitrogen reductions ranged from 4% to 39% over the simulation period with an average reduction of 22%. Ammonia nitrogen was reduced by 15% to 76% with an average reduction of 49%; this reduction was considerably higher than the nitrate reduction due to reduced sediment loadings that transport the adsorbed ammonia nitrogen. As discussed above for the edge-of-stream loadings, the reductions for nitrate and ammonia were lowest in the first year of the simulation period due to the same initial nutrient storages in the soil for both the base conditions and the BMP.

Figure 8.1 compares the frequency curves for nutrient concentrations at Marengo resulting from simulation of base and BMP conditions for the 1974-1978 period. Both the nitrate and ammonia curves indicate a general decrease of instream nutrient concentrations for the BMP scenario; extreme and median values are reduced for both constituents. Generally speaking, reductions in ammonia concentration resulting from the modeled BMP scenario were relatively more pronounced than reductions in nitrate, particularly for extreme values. For example, the 10% level for ammonia (i.e., the concentration which was exceeded 10% of the time) was reduced by 60% from the base conditions to the BMP scenario, while only a 13% reduction in nitrate occurred.

The best management practices are more effective in reducing peak concentrations of ammonia than nitrate because improved sediment erosion control prevents adsorbed ammonia from reaching the channel, while erosion control has a limited effect on the highly mobile nitrate species. Reductions for median concentrations resulting from the BMP scenario were 18% and 34% for ammonia and nitrate, respectively. The relatively large reduction in nitrate concentration for mid-range events can be attributed to two phenomena resulting from best management practices: (1) increased nitrate uptake by plants and (2) decreased groundwater flow. Large quantities of nitrate are carried to the river by groundwater flow, and reduction of instream nitrate concentrations is a natural consequence of decreasing groundwater flow and associated concentrations. On the other hand, ammonia loadings from groundwater are relatively small, and instream concentrations of ammonia are not nearly as sensitive to reductions in groundwater flow.

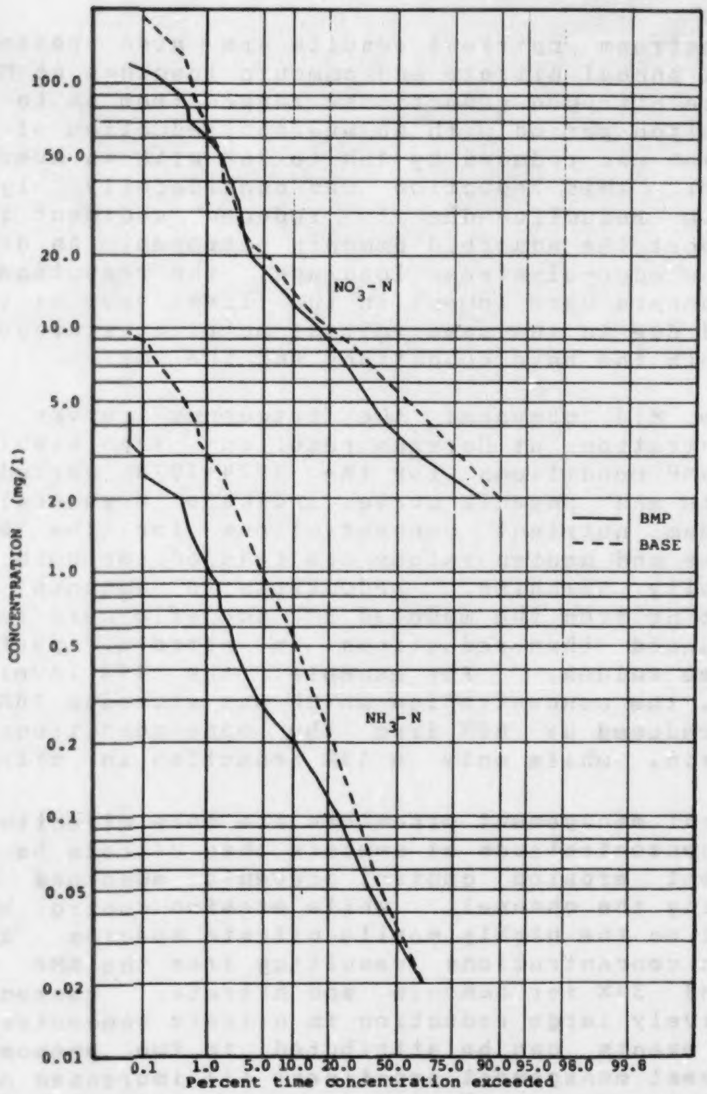

Figure 8.1 Frequency Curves for Simulated Ammonia and Nitrate at Marengo, Iowa. Base condition and nutrient BMP results are illustrated.

Risk Assessment. One of the possible uses of continuous modeling of chemical fate and transport is to evaluate the risk or exposure of aquatic organisms to various magnitudes and duration of chemical concentrations. Figure 8.2 demonstrates how the frequency, or percent of time, of acute, chronic, and sublethal conditions might be determined for a particular organism and stream given a time series of chemical concentrations. This methodology was developed in work by Onishi et al., (1979) in providing a procedure to assess the risk of chemical exposure to aquatic organisms. Using these procedures the simulated chemical concentrations under both base conditions and the BMP scenario were analyzed to determine the percent of time conditions within each region shown in Figure 8.2 would exist. The results of this analysis are shown in Table 8.5; the table title indicates a hypothetical organism because all the values observed for alachlor concentrations were considerably lower than any of the MATC (maximum acceptable toxicant concentration) values for common species of fish found in the Iowa River.

Table 8.5 also shows the reductions in the fraction of time when acute and lethal conditions exist under the simulated BMP scenario. The specific choice of MATC and lethality data chosen for this analysis resulted in no change in the percent of time when acute conditions existed, primarily because the maximum simulated value was still sufficiently large to exceed the values that define the acute region under both conditions (base conditions and BMP scenario).

A concentration of 30 ppb solution alachlor defined the single day (24-hour) acute concentration threshold for our hypothetical organism. The maximum observed solution alachlor concentrations in each year for both the base conditions and BMP scenario are listed below:

Annual maximum daily concentrations of
solution alachlor (ppb)

Year	Date	Base	BMP	% Change
1974	5/16	286.	262.	- 8.4
1975	6/15	27.	16.	-41.
1976	5/29	17.	12.	-29.
1977	5/22	2.0	1.6	-20.
1978	5/18	105.	90.	-14.

Thus, although the BMP scenario provided substantial reductions in the peak concentrations ranging from 9% to 41%, the absolute reductions in 1974 and 1978 were not sufficient to reduce the concentrations below the 30 ppb threshold used in our risk analysis.

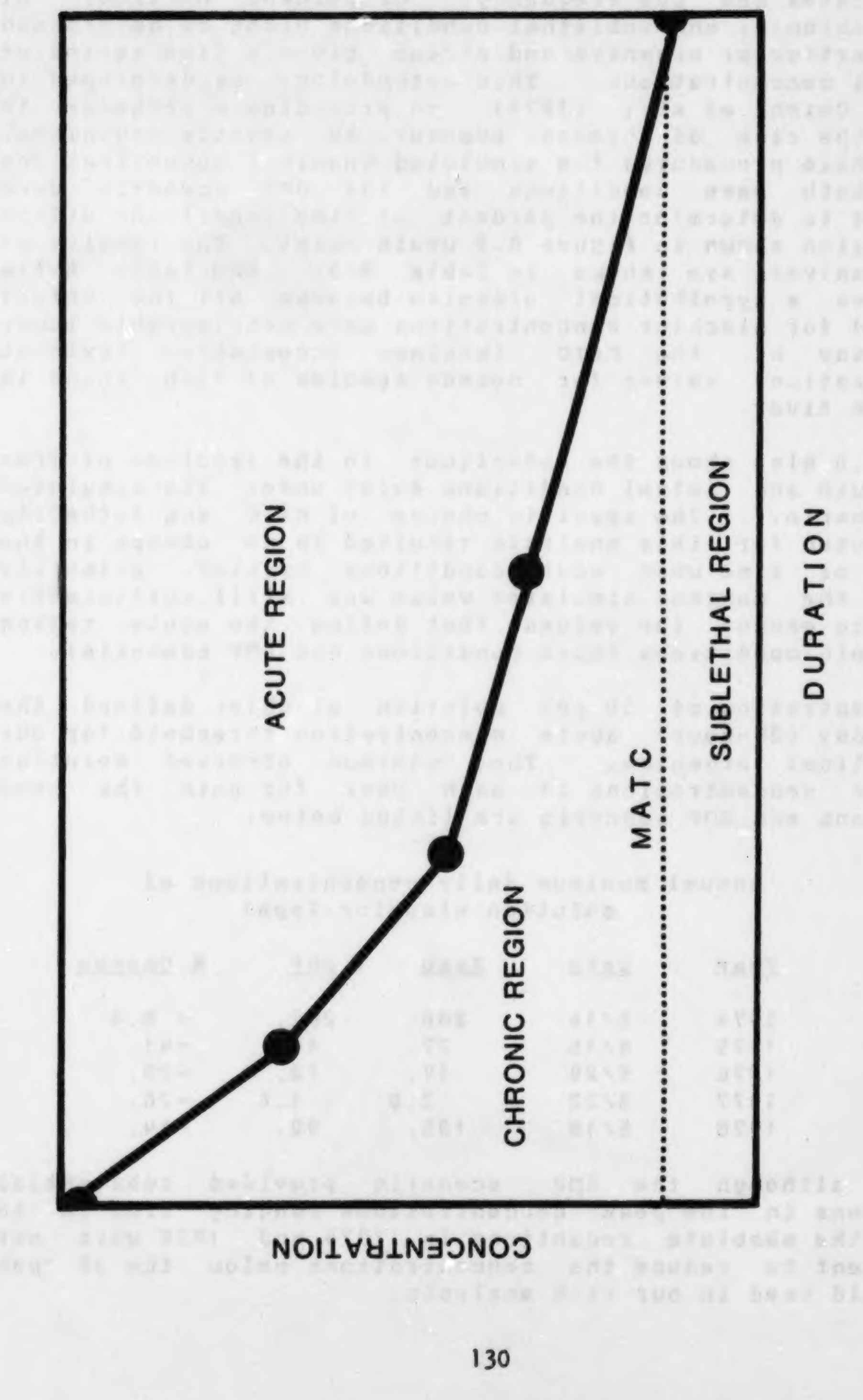

Figure 8.2 Lethality Analysis of Chemical Concentration Data

TABLE 8.5 LETHALITY ANALYSIS OF BMP SCENARIO FOR ALACHLOR IN THE IOWA RIVER AT MARENGO, IOWA

	Global Exceedance (% of time)		
	Base Conditions	BMP Scenario	% Change
Acute Region	0.49	0.49	0
Above MATC Value	3.50	2.68	-23.4
Sublethal Region (below MATC)	96.50	97.32	+ 0.8

MATC - Maximum Acceptable Toxicant Concentration
(0.003 mg/l used above)

The fraction of time when lethal conditions exist, both acute and chronic, is represented by the values listed on the line entitled "Above The MATC Value" in Table 8.5. The reductions indicate a 23% reduction in the percent of time when lethal conditions occurred in the watershed. Obviously, reductions in the percent of time for lethal conditions will correspond to an increase in time for sublethal conditions. Although the values listed here are specific to the conditions under which this BMP scenario was simulated, the overall methodology and analysis indicates how the procedures described here can be used to evaluate the effects of BMP scenarios on the resulting risk of exposure of aquatic organisms to chemicals.

Dominican Republic Hydropower Study

One of the early applications of HSPF was in a hydropower study of the Rio Yaque del Norte Basin for the Dominican Republic (Hydrocomp, Inc., 1980). Hydropower is a major source of electricity in this developing country, which is experiencing an 11% annual increase in demand. Twenty potential hydropower sites were identified and 10 potential network configurations were hypothesized. The analysis procedure consisted of the generation of 99 years of synthetic precipitation, calculation of land surface runoff, and calculation of natural streamflow at 21 sites (shown in Figure 8.3). Power generation was simulated by running the streamflow through the 10 different hydropower configurations. The time series for depth of flow (head) and flow rate were then analyzed using the GENER module to estimate the most efficient configuration (Barnwell and Johanson, 1981).

Generation of hydroelectric power involved operation of HSPF to first simulate a hypothetical 99-year streamflow period and then route the streamflow through diversion works or storage reservoirs to a penstock and turbine facility. The flow was then returned to the river for reuse further downstream.

The operation of the diversion dams was simulated using the RCHRES module of HSPF. The input to the system was natural streamflow and diverted flow, and spill was output using FTABLE to specify the diversion demand. The diversion output was multiplied by a power conversion factor to compute simulated power generated. Duration analyses of power and spill were performed using the DURANL module.

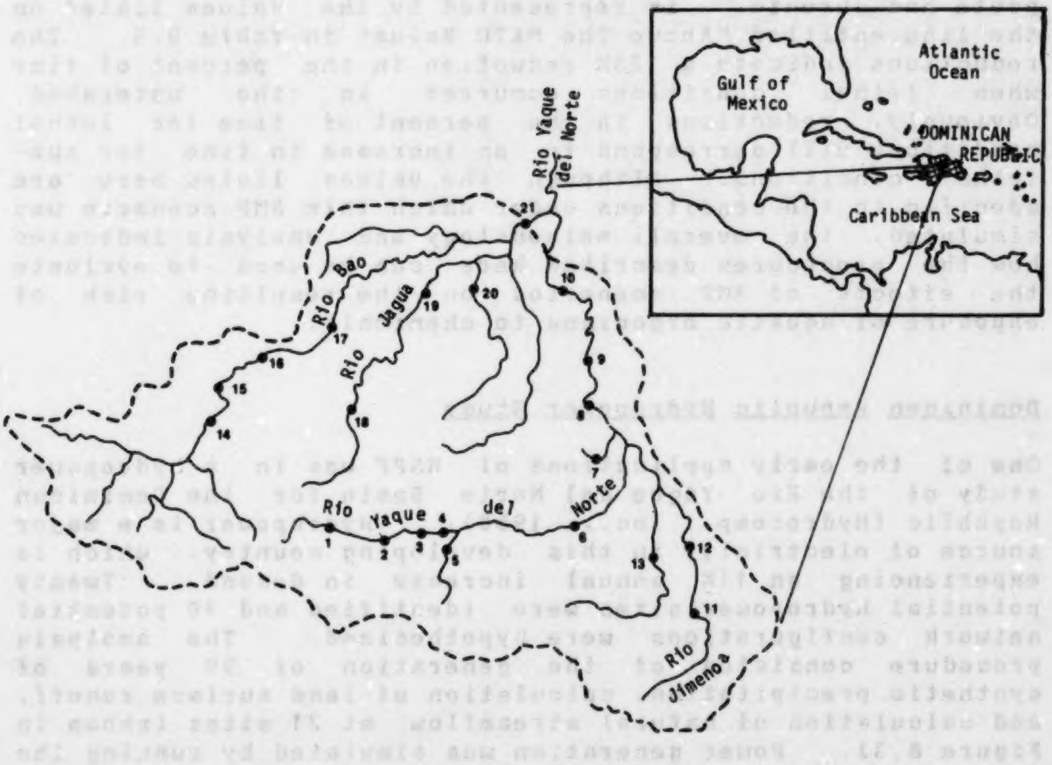
Atlantic Ocean
Gulf of Mexico
DOMINICAN REPUBLIC
Caribbean Sea
Rio Yaque del Norte
Rio Bao
Rio Jagua
Rio Yaque del Norte
Rio Jimenoa
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Figure 8.3 Location of the 21 Dam Sites for Power Generation in the Rio Yaque del Norte watershed, Dominican Republic (Hydrocomp Inc., 1980)

The storage dams were operated in a similar manner using RCHRES. The reservoir depth-storage relationship was incorporated in the FTABLE and the variable stage (head) calculated. Power generated and duration analyses were treated in the same manner as for the diversion dam analysis.

In a single HSPF run, an entire multi-diversion and storage configuration was completely analyzed. Operations proceeded in sequence from upstream to downstream, with each result routed to further operations as required by the particular configuration. Complex configurations, such as interbasin water transfers and streamflow alteration by upstream generation facilities were handled without problems.

Clinton River Stormwater Management Study

The Macomb County (Michigan) Public Works Department has used an early version of HSPF to evaluate stormwater management alternatives for small study areas within the Clinton River basin (Winn and Barnes, 1982). The objective of the study was to determine the effect of stormwater retention from upstream areas on downstream flows. The study area selected as a sample case was the Dunn-Wilcox watershed in southeast Shelby Township (Figure 8.4). This watershed within the Clinton River basin has an area of 1942 hectares (4800 acres), of which 32 percent is developed with most development occurring in the upper part of the watershed. Drainage is provided by nine county drains. In addition, five state-owned borrow pits and seven man-made lakes are available to store stormwater runoff. Future development in the watershed is expected to increase the severity of flood problems.

Prior to the investigation of possible stormwater management alternatives, the model was calibrated for the entire Clinton River basin and all sub-basins containing streamflow records. Following the calibration of the model, 48 years of simulated streamflow data were created by the model using historical precipitation data and present land use conditions. This was done to generate a consistently long period of streamflow data for the entire basin without having to consider the effect of land use changes on the recorded flow data in the past 48 years. The simulated streamflow record is more representative of the runoff that would occur under current land conditions in response to historical meteorological data, than the observed historical streamflow record.

After the completion of calibration, the June 1968 flood was selected as the study flood for evaluating stormwater management alternatives on the Dunn-Wilcox watershed (Figure 8.5). This flood is the largest of record. Two sets of flows were simulated for the June 1968 event. The first was using existing conditions (present land use patterns); the second assumed full development of the watershed in accordance with the Township's Master Land Use and Zoning Plan.

These flows were then routed through a combination of different drain facilities with and without retention. The drain facilities consisted of (1) drains in their present condition, (2) enlarged drain channels, and (3) enlarged drain channels with extra stormwater storage (wide channel tops and lake storage).

Results were analyzed for three sets of land use and drain channel combinations. These combinations are: (1) present land use and present channels, (2) future land use and improved (enlarged) channels, and (3) future land use and

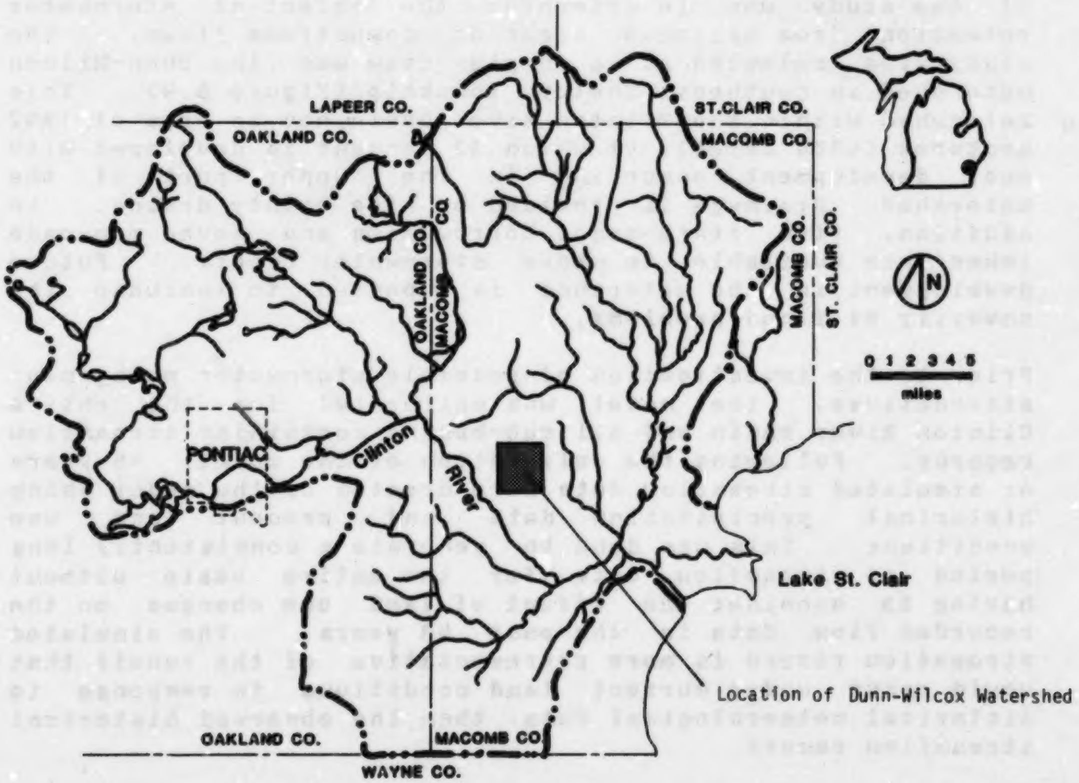
LAPEER CO.
OAKLAND CO.
ST.CLAIR CO.
MACOMB CO.
OAKLAND CO.
MACOMB CO.
MACOMB CO.
ST. CLAIR CO.
N
0 1 2 3 4 5
miles
PONTIAC
Clinton
River
Lake St. Clair
Location of Dunn-Wilcox Watershed
OAKLAND CO.
MACOMB CO.
WAYNE CO.

Figure 8.4 Clinton River Drainage Basin, Michigan

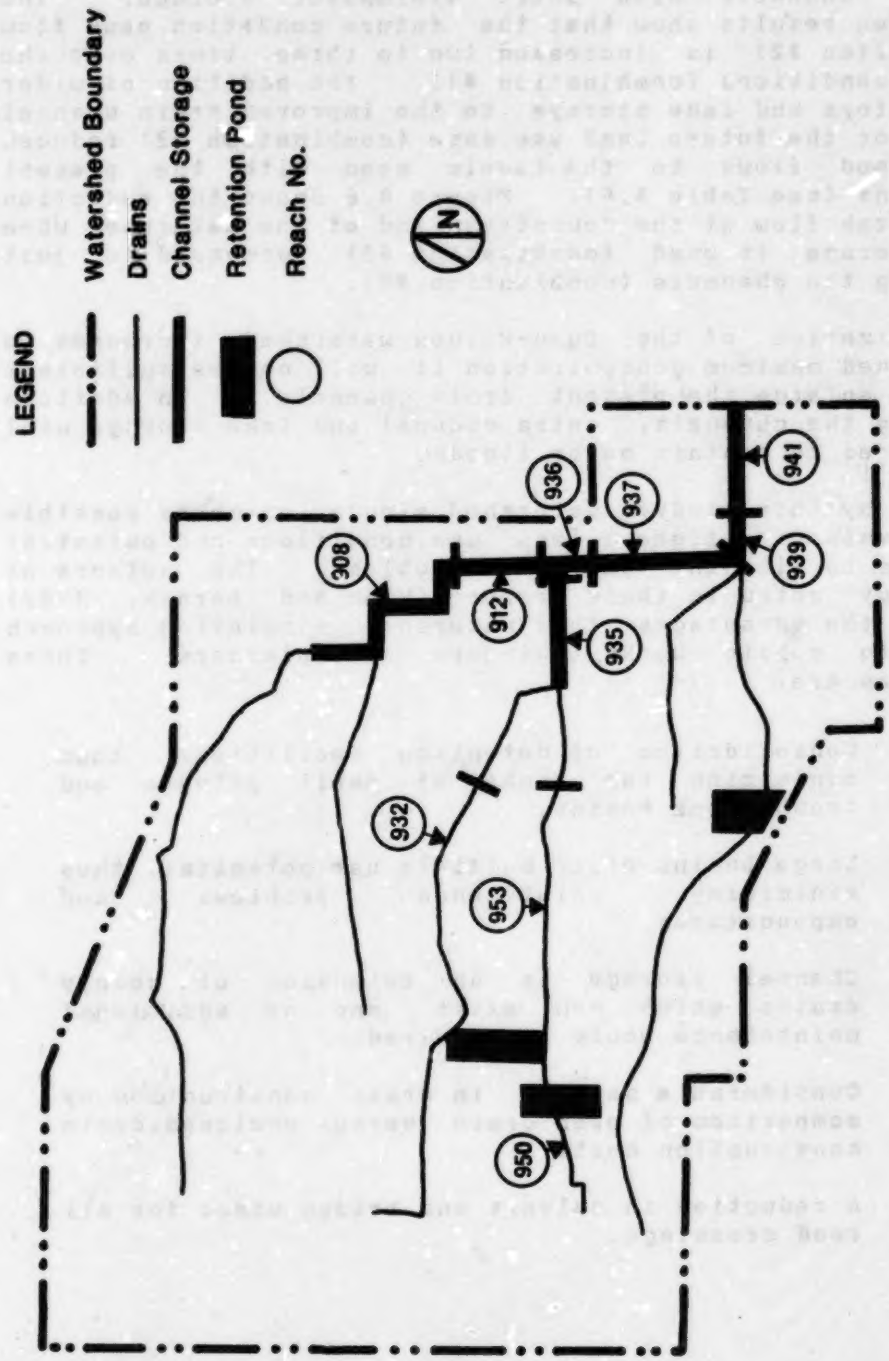
LEGEND
Watershed Boundary
Drains
Channel Storage
Retention Pond
Reach No.
N
308
936
937
941
912
935
939
932
953
950

Figure 8.5 Dunn-Wilcox Watershed

improved channels with extra stormwater storage. The simulation results show that the future condition peak flow (combination #2) is increased two to three times over the present conditions (combination #1). The addition of wider channel tops and lake storage to the improved drain channel system for the future land use case (combination #3) reduces peak flood flows to the levels seen with the present conditions (see Table 8.6). Figure 8.6 shows the reduction in the peak flow at the downstream end of the watershed when extra storage is used (combination #3) compared to just improving the channels (combination #2).

As urbanization of the Dunn-Wilcox watershed increases to its planned maximum concentration it will not be sufficient to just enlarge the present drain channels. In addition enlarging the channels, extra channel and lake storage will be required to contain major floods.

As shown by this study, watershed simulation makes possible the analysis of different land use conditions and potential solutions to flooding and other problems. The authors of this study noted in their report (Winn and Barnes, 1982) some of the advantages this watershed simulation approach offers to public works engineers and planners. These advantages are:

1. Consolidation of detention facilities, thus minimizing the number of small private and troublesome basins.

2. Large basins offer multiple use potential, thus minimizing maintenance problems and expenditures.

3. Channel storage is an extension of county drains which now exist and no additional maintenance would be required.

4. Considerable savings in drain construction by comparison of open drain versus enclosed drain construction costs.

5. A reduction in culvert and bridge sizes for all road crossings.

TABLE 8.6 COMPARISON OF MAXIMUM FLOWS (CFS) FOR REACHES WITH CHANNEL STORAGE

Reach Number	Combination #1	Combination #2	Combination #3
908	258	723	300
912	321	895	300
935		271	150
936	533	1458	450
937	534	1456	375
939	635	1755	625
941	663	1815	600

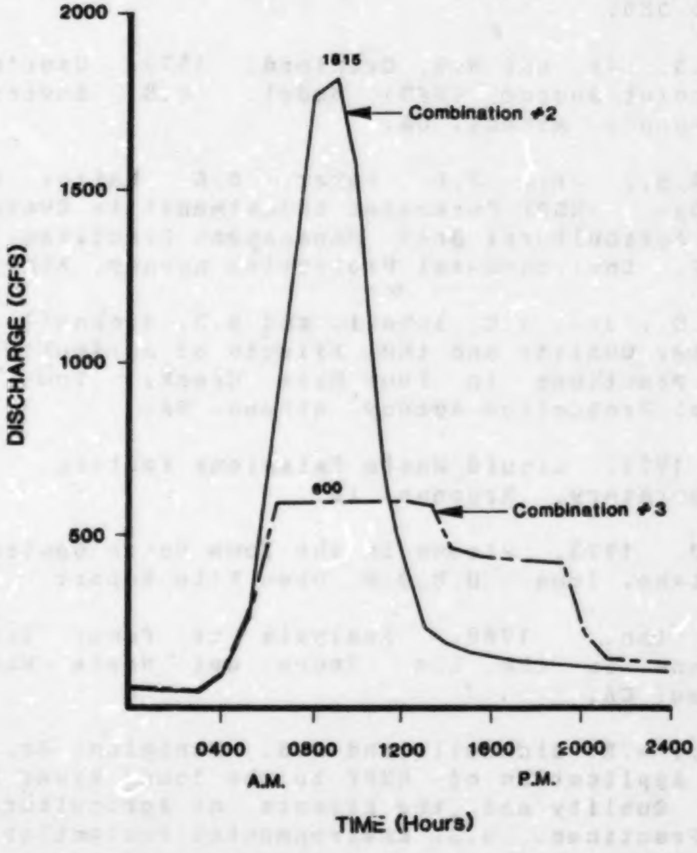

Figure 8.6 Hydrograph of Reach 941 for June 26, 1968, Event

SECTION 9

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APPENDIX A

Sample HSPF Input Sequence

This input sequence was developed and used in the Iowa River Study. The sequence provides the input instructions and parameters necessary to simulate hydrology, hydraulics, sediment and pesticide processes on the basin land surface and within the Iowa River.

```
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//HSPF7 EXEC PGM=HSPF,REGION=512K
//STEPLIB DD DSN=WYL.XA.Q11.HSPF7.LM,DISP=SHR,
//     UNIT=DISK,VOL=SER=PUB012
//         DD DSN=SYS2.F03.PROD.LINKLIB,DISP=SHR
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//     DCB=(BUFNO=1),UNIT=DISK,VOL=SER=PUB012,LABEL=(,,,IN)
//FT02F001 DD DSN=WYL.XA.R72.HSPF.TEMP.UCIFL,DISP=(OLD,KEEP),
//     UNIT=DISK,VOL=SER=PUB010,SPACE=(84,(2000,5)),
//     DCB=(RECFM=F,BLKSIZE=84,BUFNO=1)
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//     DCB=(BUFNO=1),UNIT=DISK,VOL=SER=PUB012,LABEL=(,,,IN)
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RUN

GLOBAL
  IOWA RIVER: PERLND/RCHRES (RUNOFF, SEDIMENT, & PESTICIDE) CALIB #2
  START       1974 01 01 00:00  END    1978 12 31 24:00
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1 TSSFL     18
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT 02:00
      PERLND       7
      DISPLY      17
      PERLND       8
      DISPLY      18
      PERLND       9
      DISPLY      19
      RCHRES      13
      PLTGEN       1
      DISPLY       5
      RCHRES      12
      PERLND       4
      DISPLY      14
      PERLND       5
      DISPLY      15
      PERLND       6
      DISPLY      16
      RCHRES      11
      RCHRES      10
      RCHRES       9
      RCHRES       8
      RCHRES       7
      PLTGEN       2
      DISPLY       7
      DISPLY      20
      DISPLY      21
      GENER        1
      DISPLY      22
      DISPLY      23
      PERLND       1
      DISPLY      11
      PERLND       2
      DISPLY      12
      PERLND       3
      DISPLY      13
      RCHRES       6
      RCHRES       5
      RCHRES       4
      RCHRES       3
      RCHRES       2
      RCHRES       1
      PLTGEN       3
      PLTGEN       4
      PLTGEN       5
      GENER        2
      PLTGEN       6
      PLTGEN       7
      PLTGEN       8
      DISPLY       1
      DISPLY       3
      DISPLY       9
      DISPLY      24
      DISPLY      25
      DISPLY      26
      DISPLY      27
    END INGRP
END OPN SEQUENCE

SPEC-ACTIONS
  OPERATIONS         DATE AND TIME  TYPE-       ADDR  ACTION-  QUANTITY ***
  TYPE    # TO#                      CODE               CODE            ***
```

```
INCREASE INFILT DUE TO THAWED GROUND   ***   (UNITS ARE IN/IVL)
PERLND  1         1974/03/31         3       334          1      0.14
PLOWING                                ***
PERLND  1         1974/04/15 12      3       918          1       1.2
INCREASE INFILT FOR TILLAGE            ***
PERLND  1         1974/04/15 12      3       334          1      0.18
DISKING                                ***
PERLND  1         1974/05/15 12      3       918          1       2.0
ALACHLOR APPLICATION OF 2.5 LB/AC *** APPLIED TO SURFACE ADSORBED STORAGE
(TOTAL RATE DISTRIBUTED OVER THREE *** SEPARATE APPLICATIONS: 25% 50% 25%)
PERLND  1         1974/05/24 12      3      2716          2     0.625
PERLND  1         1974/06/03 12      3      2716          2      1.25
PERLND  1         1974/06/11 12      3      2716          2     0.625
RESET ALACHLOR SURFACE DECAY RATE  ***
PERLND  1         1974/06/20         3      2576          1      0.06
CULTIVATION                            ***
PERLND  1         1974/06/21 12      3       918          1       1.5
CULTIVATION                            ***
PERLND  1         1974/07/14 12      3       918          1       1.5
RESET INFILT TO NOMINAL VALUE          ***
PERLND  1         1974/08/15         3       334          1      0.14
REDUCE INFILT FOR FROZEN GROUND        ***
PERLND  1         1974/12/15         3       334          1      0.08

PERLND  1         1975/03/31         3       334          1      0.14
PERLND  1         1975/04/15 12      3       918          1       1.2
PERLND  1         1975/04/15 12      3       334          1      0.18
PERLND  1         1975/05/15 12      3       918          1       2.0
PERLND  1         1975/05/24 12      3      2716          2     0.625
PERLND  1         1975/06/03 12      3      2716          2      1.25
PERLND  1         1975/06/10 12      3      2716          2     0.625
PERLND  1         1975/06/20         3      2576          1      0.06
PERLND  1         1975/06/21 12      3       918          1       1.5
PERLND  1         1975/07/14 12      3       918          1       1.5
PERLND  1         1975/08/15         3       334          1      0.14
PERLND  1         1975/12/15         3       334          1      0.08

PERLND  1         1976/03/31         3       334          1      0.14
PERLND  1         1976/04/16 12      3       918          1       1.2
PERLND  1         1976/04/16 12      3       334          1      0.18
PERLND  1         1976/05/14 12      3       918          1       2.0
PERLND  1         1976/05/25 12      3      2716          2     0.625
PERLND  1         1976/06/03 12      3      2716          2      1.25
PERLND  1         1976/06/11 12      3      2716          2     0.625
PERLND  1         1976/06/20         3      2576          1      0.06
PERLND  1         1976/06/21 12      3       918          1       1.5
PERLND  1         1976/07/14 12      3       918          1       1.5
PERLND  1         1976/08/15         3       334          1      0.14
PERLND  1         1976/12/15         3       334          1      0.08

PERLND  1         1977/03/31         3       334          1      0.14
PERLND  1         1977/04/15 12      3       918          1       1.2
PERLND  1         1977/04/15 12      3       334          1      0.18
PERLND  1         1977/05/16 12      3       918          1       2.0
PERLND  1         1977/05/25 12      3      2716          2     0.625
PERLND  1         1977/06/03 12      3      2716          2      1.25
PERLND  1         1977/06/10 12      3      2716          2     0.625
PERLND  1         1977/06/20         3      2576          1      0.06
PERLND  1         1977/06/21 12      3       918          1       1.5
PERLND  1         1977/07/14 12      3       918          1       1.5
PERLND  1         1977/08/15         3       334          1      0.14
PERLND  1         1977/12/15         3       334          1      0.08

PERLND  1         1978/03/31         3       334          1      0.14
PERLND  1         1978/04/15 12      3       918          1       1.2
PERLND  1         1978/04/15 12      3       334          1      0.18
PERLND  1         1978/05/15 12      3       918          1       2.0
PERLND  1         1978/05/25 12      3      2716          2     0.625
PERLND  1         1978/06/04 12      3      2716          2      1.25
PERLND  1         1978/06/10 12      3      2716          2     0.625
PERLND  1         1978/06/20         3      2576          1      0.06
PERLND  1         1978/06/21 12      3       918          1       1.5
PERLND  1         1978/07/14 12      3       918          1       1.5
PERLND  1         1978/08/15         3       334          1      0.14
PERLND  1         1978/12/15         3       334          1      0.08

INCREASE INFILT DUE TO THAWED GROUND   ***   (UNITS ARE IN/IVL)
PERLND  2         1974/03/31         3       334          1      0.14
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DISKING                                    ***
PERLND  2          1974/04/25 12      3          334          1      0.18
DISKING                                    ***
PERLND  2          1974/04/25 12      3          918          1       2.0
ALACHLOR APPLICATION OF 2.5 LB/AC *** APPLIED TO SURFACE ADSORBED STORAGE
(TOTAL RATE DISTRIBUTED OVER THREE *** SEPARATE APPLICATIONS: 25% 50% 25%)
PERLND  2          1974/05/01 12      3         2716          2     0.625
PERLND  2          1974/05/15 12      3         2716          2      1.25
PERLND  2          1974/05/20 12      3         2716          2     0.625
RESET ALACHLOR SURFACE DECAY RATE  ***
PERLND  2          1974/05/30         3         2576          1      0.06
CULTIVATION                                ***
PERLND  2          1974/06/11 12      3          918          1       1.5
CULTIVATION                                ***
PERLND  2          1974/07/01 12      3          918          1       1.5
RESET INFILT TO NOMINAL VALUE              ***
PERLND  2          1974/08/15         3          334          1      0.14
REDUCE INFILT FOR FROZEN GROUND            ***
PERLND  2          1974/12/16         3          334          1      0.08

PERLND  2          1975/03/31         3          334          1      0.14
PERLND  2          1975/04/25 12      3          334          1      0.18
PERLND  2          1975/04/25 12      3          918          1       2.0
PERLND  2          1975/05/01 12      3         2716          2     0.625
PERLND  2          1975/05/10 12      3         2716          2      1.25
PERLND  2          1975/05/20 12      3         2716          2     0.625
PERLND  2          1975/05/30         3         2576          1      0.06
PERLND  2          1975/06/10 12      3          918          1       1.5
PERLND  2          1975/07/01 12      3          918          1       1.5
PERLND  2          1975/08/15         3          334          1      0.14
PERLND  2          1975/12/15         3          334          1      0.08

PERLND  2          1976/03/31         3          334          1      0.14
PERLND  2          1976/04/26 12      3          334          1      0.18
PERLND  2          1976/04/26 12      3          918          1       2.0
PERLND  2          1976/05/01 12      3         2716          2     0.625
PERLND  2          1976/05/10 12      3         2716          2      1.25
PERLND  2          1976/05/20 12      3         2716          2     0.625
PERLND  2          1976/05/30         3         2576          1      0.06
PERLND  2          1976/06/11 12      3          918          1       1.5
PERLND  2          1976/07/01 12      3          918          1       1.5
PERLND  2          1976/08/15         3          334          1      0.14
PERLND  2          1976/12/15         3          334          1      0.08

PERLND  2          1977/03/31         3          334          1      0.14
PERLND  2          1977/04/25 12      3          334          1      0.18
PERLND  2          1977/04/25 12      3          918          1       2.0
PERLND  2          1977/05/01 12      3         2716          2     0.625
PERLND  2          1977/05/10 12      3         2716          2      1.25
PERLND  2          1977/05/19 12      3         2716          2     0.625
PERLND  2          1977/05/29         3         2576          1      0.06
PERLND  2          1977/06/10 12      3          918          1       1.5
PERLND  2          1977/07/01 12      3          918          1       1.5
PERLND  2          1977/08/14         3          334          1      0.14
PERLND  2          1977/12/15         3          334          1      0.08

PERLND  2          1978/03/31         3          334          1      0.14
PERLND  2          1978/04/25 12      3          334          1      0.18
PERLND  2          1978/04/25 12      3          918          1       2.0
PERLND  2          1978/05/01 12      3         2716          2     0.625
PERLND  2          1978/05/10 12      3         2716          2      1.25
PERLND  2          1978/05/20 12      3         2716          2     0.625
PERLND  2          1978/05/30         3         2576          1      0.06
PERLND  2          1978/06/10 12      3          918          1       1.5
PERLND  2          1978/07/01 12      3          918          1       1.5
PERLND  2          1978/08/15         3          334          1      0.14
PERLND  2          1978/12/15         3          334          1      0.08

INCREASE INFILT DUE TO THAWED GROUND    ***   (UNITS ARE IN/IVL)
PERLND  3          1974/03/31         3          334          1      0.22
REDUCE INFILT FOR FROZEN GROUND            ***
PERLND  3          1974/12/16         3          334          1      0.12

PERLND  3          1975/03/31         3          334          1      0.22
PERLND  3          1975/12/15         3          334          1      0.12

PERLND  3          1976/03/31         3          334          1      0.22
PERLND  3          1976/12/15         3          334          1      0.12

PERLND  3          1977/03/31         3          334          1      0.22
PERLND  3         1977/12/15       3       334         1     0.12

PERLND  3         1978/03/31       3       334         1     0.22
PERLND  3         1978/12/15       3       334         1     0.12

INCREASE INFILT DUE TO THAWED GROUND   ***   (UNITS ARE IN/IVL)
PERLND  4         1974/04/07       3       334         1     0.16
PLOWING                                ***
PERLND  4         1974/04/22 12    3       918         1      1.2
INCREASE INFILT FOR TILLAGE            ***
PERLND  4         1974/04/22 12    3       334         1     0.22
DISKING                                ***
PERLND  4         1974/05/22 12    3       918         1      2.0
ALACHLOR APPLICATION OF 2.5 LB/AC *** APPLIED TO SURFACE ADSORBED STORAGE
(TOTAL RATE DISTRIBUTED OVER THREE *** SEPARATE APPLICATIONS: 25% 50% 25%)
PERLND  4         1974/05/30 12    3      2716         2    0.625
PERLND  4         1974/06/05 12    3      2716         2     1.25
PERLND  4         1974/06/15 12    3      2716         2    0.625
RESET ALACHLOR SURFACE DECAY RATE  ***
PERLND  4         1974/06/25       3      2576         1     0.06
CULTIVATION                            ***
PERLND  4         1974/06/26 12    3       918         1      1.5
CULTIVATION                            ***
PERLND  4         1974/07/21 12    3       918         1      1.5
RESET INFILT TO NOMINAL VALUE          ***
PERLND  4         1974/08/20       3       334         1     0.16
REDUCE INFILT FOR FROZEN GROUND        ***
PERLND  4         1974/12/08       3       334         1     0.10

PERLND  4         1975/04/07       3       334         1     0.16
PERLND  4         1975/04/20 12    3       918         1      1.2
PERLND  4         1975/04/20 12    3       334         1     0.22
PERLND  4         1975/05/22 12    3       918         1      2.0
PERLND  4         1975/05/30 12    3      2716         2    0.625
PERLND  4         1975/06/07 12    3      2716         2     1.25
PERLND  4         1975/06/15 12    3      2716         2    0.625
PERLND  4         1975/06/25       3      2576         1     0.06
PERLND  4         1975/06/26 12    3       918         1      1.5
PERLND  4         1975/07/21 12    3       918         1      1.5
PERLND  4         1975/08/20       3       334         1     0.16
PERLND  4         1975/12/07       3       334         1     0.10

PERLND  4         1976/04/07       3       334         1     0.16
PERLND  4         1976/04/22 12    3       918         1      1.2
PERLND  4         1976/04/22 12    3       334         1     0.22
PERLND  4         1976/05/21 12    3       918         1      2.0
PERLND  4         1976/05/30 12    3      2716         2    0.625
PERLND  4         1976/06/08 12    3      2716         2     1.25
PERLND  4         1976/06/16 12    3      2716         2    0.625
PERLND  4         1976/06/25       3      2576         1     0.06
PERLND  4         1976/06/26 12    3       918         1      1.5
PERLND  4         1976/07/21 12    3       918         1      1.5
PERLND  4         1976/08/20       3       334         1     0.16
PERLND  4         1976/12/07       3       334         1     0.10

PERLND  4         1977/04/07       3       334         1     0.16
PERLND  4         1977/04/22 12    3       918         1      1.2
PERLND  4         1977/04/22 12    3       334         1     0.22
PERLND  4         1977/05/22 12    3       918         1      2.0
PERLND  4         1977/05/30 12    3      2716         2    0.625
PERLND  4         1977/06/07 12    3      2716         2     1.25
PERLND  4         1977/06/15 12    3      2716         2    0.625
PERLND  4         1977/06/25       3      2576         1     0.06
PERLND  4         1977/06/26 12    3       918         1      1.5
PERLND  4         1977/07/21 12    3       918         1      1.5
PERLND  4         1977/08/20       3       334         1     0.16
PERLND  4         1977/12/06       3       334         1     0.10

PERLND  4         1978/04/08       3       331         1     0.16
PERLND  4         1978/04/21 12    3       918         1      1.2
PERLND  4         1978/04/21 12    3       334         1     0.22
PERLND  4         1978/05/22 12    3       918         1      2.0
PERLND  4         1978/05/30 12    3      2716         2    0.625
PERLND  4         1978/06/08 12    3      2716         2     1.25
PERLND  4         1978/06/13 12    3      2716         2    0.625
PERLND  4         1978/06/23       3      2576         1     0.06
PERLND  4         1978/06/26 12    3       918         1      1.5
PERLND  4         1978/07/21 12    3       918         1      1.5
PERLND  4         1978/08/20       3       334         1     0.16
PERLND  4         1978/12/06       3       334         1     0.10
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INCREASE INFILT DUE TO THAWED GROUND    ***   (UNITS ARE IN/IVL)
PERLND  5         1974/04/07          3       334         1    0.16
DISKING                                 ***
PERLND  5         1974/04/30 12       3       334         1    0.22
DISKING                                 ***
PERLND  5         1974/04/30 12       3       918         1     2.0
ALACHLOR APPLICATION OF 2.5 LB/AC *** APPLIED TO SURFACE ADSORBED STORAGE
(TOTAL RATE DISTRIBUTED OVER THREE *** SEPARATE APPLICATIONS: 25% 50% 25%)
PERLND  5         1974/05/05 12       3      2716         2   0.625
PERLND  5         1974/05/15 12       3      2716         2    1.25
PERLND  5         1974/05/25 12       3      2716         2   0.625
RESET ALACHLOR SURFACE DECAY RATE  ***
PERLND  5         1974/06/05          3      2576         1    0.06
CULTIVATION                             ***
PERLND  5         1974/06/15 12       3       918         1     1.5
CULTIVATION                             ***
PERLND  5         1974/07/07 12       3       918         1     1.5
RESET INFILT TO NOMINAL VALUE           ***
PERLND  5         1974/08/20          3       334         1    0.16
REDUCE INFILT FOR FROZEN GROUND         ***
PERLND  5         1974/12/08          3       334         1    0.10

PERLND  5         1975/04/07          3       334         1    0.16
PERLND  5         1975/04/30 12       3       334         1    0.22
PERLND  5         1975/04/30 12       3       918         1     2.0
PERLND  5         1975/05/05 12       3      2716         2   0.625
PERLND  5         1975/05/15 12       3      2716         2    1.25
PERLND  5         1975/05/25 12       3      2716         2   0.625
PERLND  5         1975/06/05          3      2576         1    0.06
PERLND  5         1975/06/15 12       3       918         1     1.5
PERLND  5         1975/07/07 12       3       918         1     1.5
PERLND  5         1975/08/20          3       334         1    0.16
PERLND  5         1975/12/07          3       334         1    0.10

PERLND  5         1976/04/07          3       334         1    0.16
PERLND  5         1976/04/30 12       3       334         1    0.22
PERLND  5         1976/04/30 12       3       918         1     2.0
PERLND  5         1976/05/05 12       3      2716         2   0.625
PERLND  5         1976/05/17 12       3      2716         2    1.25
PERLND  5         1976/05/25 12       3      2716         2   0.625
PERLND  5         1976/06/05          3      2576         1    0.06
PERLND  5         1976/06/16 12       3       918         1     1.5
PERLND  5         1976/07/07 12       3       918         1     1.5
PERLND  5         1976/08/20          3       334         1    0.16
PERLND  5         1976/12/07          3       334         1    0.10

PERLND  5         1977/04/07          3       334         1    0.16
PERLND  5         1977/04/30 12       3       334         1    0.22
PERLND  5         1977/04/30 12       3       918         1     2.0
PERLND  5         1977/05/05 12       3      2716         2   0.625
PERLND  5         1977/05/15 12       3      2716         2    1.25
PERLND  5         1977/05/25 12       3      2716         2   0.625
PERLND  5         1977/06/05          3      2576         1    0.06
PERLND  5         1977/06/15 12       3       918         1     1.5
PERLND  5         1977/07/07 12       3       918         1     1.5
PERLND  5         1977/08/20          3       334         1    0.16
PERLND  5         1977/12/06          3       334         1    0.10

PERLND  5         1978/04/08          3       334         1    0.16
PERLND  5         1978/04/30 12       3       334         1    0.22
PERLND  5         1978/04/30 12       3       918         1     2.0
PERLND  5         1978/05/05 12       3      2716         2   0.625
PERLND  5         1978/05/15 12       3      2716         2    1.25
PERLND  5         1978/05/25 12       3      2716         2   0.625
PERLND  5         1978/06/05          3      2576         1    0.06
PERLND  5         1978/06/13 12       3       918         1     1.5
PERLND  5         1978/07/09 12       3       918         1     1.5
PERLND  5         1978/08/20          3       334         1    0.16
PERLND  5         1978/12/06          3       334         1    0.10

INCREASE INFILT DUE TO THAWED GROUND    ***   (UNITS ARE IN/IVL)
PERLND  6         1974/04/05          3       334         1    0.26
REDUCE INFILT FOR FROZEN GROUND         ***
PERLND  6         1974/12/10          3       334         1    0.14

PERLND  6         1975/04/05          3       334         1    0.26
PERLND  6         1975/12/10          3       334         1    0.14
PERLND  6         1976/04/05         3        334         1      0.26
PERLND  6         1976/12/10         3        334         1      0.14

PERLND  6         1977/04/05         3        334         1      0.26
PERLND  6         1977/12/10         3        334         1      0.14

PERLND  6         1978/04/04         3        334         1      0.26
PERLND  6         1978/12/10         3        334         1      0.14

INCREASE INFILT DUE TO THAWED GROUND   ***  (UNITS ARE IN/IVL)
PERLND  7         1974/04/15         3        334         1      0.20
PLOWING                                ***
PERLND  7         1974/04/29 12      3        918         1       1.2
INCREASE INFILT FOR TILLAGE            ***
PERLND  7         1974/04/29 12      3        334         1      0.26
DISKING                                ***
PERLND  7         1974/05/29 12      3        918         1       2.0
ALACHLOR APPLICATION OF 2.5 LB/AC *** APPLIED TO SURFACE ADSORBED STORAGE
(TOTAL RATE DISTRIBUTED OVER THREE *** SEPARATE APPLICATIONS: 25% 50% 25%)
PERLND  7         1974/06/05 12      3       2716         2     0.625
PERLND  7         1974/06/13 12      3       2716         2      1.25
PERLND  7         1974/06/20 12      3       2716         2     0.625
RESET ALACHLOR SURFACE DECAY RATE  ***
PERLND  7         1974/06/30         3       2576         1      0.06
CULTIVATION                            ***
PERLND  7         1974/07/01 12      3        918         1       1.5
CULTIVATION                            ***
PERLND  7         1974/07/25 12      3        918         1       1.5
RESET INFILT TO NOMINAL VALUE          ***
PERLND  7         1974/08/25         3        334         1      0.20
REDUCE INFILT FOR FROZEN GROUND        ***
PERLND  7         1974/12/01         3        334         1      0.12

PERLND  7         1975/04/16         3        334         1      0.20
PERLND  7         1975/04/29 12      3        918         1       1.2
PERLND  7         1975/04/29 12      3        334         1      0.26
PERLND  7         1975/05/30 12      3        918         1       2.0
PERLND  7         1975/06/05 12      3       2716         2     0.625
PERLND  7         1975/06/13 12      3       2716         2      1.25
PERLND  7         1975/06/20 12      3       2716         2     0.625
PERLND  7         1975/06/30         3       2576         1      0.06
PERLND  7         1975/07/01 12      3        918         1       1.5
PERLND  7         1975/07/25 12      3        918         1       1.5
PERLND  7         1975/08/25         3        334         1      0.20
PERLND  7         1975/12/02         3        334         1      0.12

PERLND  7         1976/04/15         3        334         1      0.20
PERLND  7         1976/04/29 12      3        918         1       1.2
PERLND  7         1976/04/29 12      3        334         1      0.26
PERLND  7         1976/05/27 12      3        918         1       2.0
PERLND  7         1976/06/05 12      3       2716         2     0.625
PERLND  7         1976/06/13 12      3       2716         2      1.25
PERLND  7         1976/06/20 12      3       2716         2     0.625
PERLND  7         1976/06/30         3       2576         1      0.06
PERLND  7         1976/07/01 12      3        918         1       1.5
PERLND  7         1976/07/25 12      3        918         1       1.5
PERLND  7         1976/08/25         3        334         1      0.20
PERLND  7         1976/12/02         3        334         1      0.12

PERLND  7         1977/04/15         3        334         1      0.20
PERLND  7         1977/04/29 12      3        918         1       1.2
PERLND  7         1977/04/29 12      3        334         1      0.26
PERLND  7         1977/05/30 12      3        918         1       2.0
PERLND  7         1977/06/05 12      3       2716         2     0.625
PERLND  7         1977/06/13 12      3       2716         2      1.25
PERLND  7         1977/06/20 12      3       2716         2     0.625
PERLND  7         1977/06/30         3       2576         1      0.06
PERLND  7         1977/07/01 12      3        918         1       1.5
PERLND  7         1977/07/25 12      3        918         1       1.5
PERLND  7         1977/08/25         3        334         1      0.20
PERLND  7         1977/12/01         3        334         1      0.12

PERLND  7         1978/04/15         3        334         1      0.20
PERLND  7         1978/04/29 12      3        918         1       1.2
PERLND  7         1978/04/29 12      3        334         1      0.26
PERLND  7         1978/05/29 12      3        918         1       2.0
PERLND  7         1978/06/05 12      3       2716         2     0.625
PERLND  7         1978/06/13 12      3       2716         2      1.25
PERLND  7         1978/06/21 12      3       2716         2     0.625
PERLND  7         1978/06/30         3       2576         1      0.06
PERLND  7          1978/07/01 12     3        918         1       1.5
PERLND  7          1978/07/25 12     3        918         1       1.5
PERLND  7          1978/08/25        3        334         1      0.20
PERLND  7          1978/12/01        3        334         1      0.12

INCREASE INFILT DUE TO THAWED GROUND      ***   (UNITS ARE IN/IVL)
PERLND  8          1974/04/15        3        334         1      0.20
DISKING                                   ***
PERLND  8          1974/05/06 12     3        334         1      0.26
DISKING                                   ***
PERLND  8          1974/05/06 12     3        918         1       2.0
ALACHLOR APPLICATION OF 2.5 LB/AC *** APPLIED TO SURFACE ADSORBED STORAGE
(TOTAL RATE DISTRIBUTED OVER THREE *** SEPARATE APPLICATIONS: 25% 50% 25%)
PERLND  8          1974/05/11 12     3       2716         2     0.625
PERLND  8          1974/05/20 12     3       2716         2      1.25
PERLND  8          1974/05/30 12     3       2716         2     0.625
RESET ALACHLOR SURFACE DECAY RATE  ***
PERLND  8          1974/06/10        3       2576         1      0.06
CULTIVATION                               ***
PERLND  8          1974/06/20 12     3        918         1       1.5
CULTIVATION                               ***
PERLND  8          1974/07/15 12     3        918         1       1.5
RESET INFILT TO NOMINAL VALUE             ***
PERLND  8          1974/08/25        3        334         1      0.20
REDUCE INFILT FOR FROZEN GROUND           ***
PERLND  8          1974/12/01        3        334         1      0.12

PERLND  8          1975/04/13        3        334         1      0.20
PERLND  8          1975/05/07 12     3        334         1      0.26
PERLND  8          1975/05/07 12     3        918         1       2.0
PERLND  8          1975/05/09 12     3       2716         2     0.625
PERLND  8          1975/05/20 12     3       2716         2      1.25
PERLND  8          1975/05/30 12     3       2716         2     0.625
PERLND  8          1975/06/10        3       2576         1      0.06
PERLND  8          1975/06/20 12     3        918         1       1.5
PERLND  8          1975/07/15 12     3        918         1       1.5
PERLND  8          1975/08/25        3        334         1      0.20
PERLND  8          1975/12/02        3        334         1      0.12

PERLND  8          1976/04/15        3        334         1      0.20
PERLND  8          1976/05/07 12     3        334         1      0.26
PERLND  8          1976/05/07 12     3        918         1       2.0
PERLND  8          1976/05/10 12     3       2716         2     0.625
PERLND  8          1976/05/20 12     3       2716         2      1.25
PERLND  8          1976/05/30 12     3       2716         2     0.625
PERLND  8          1976/06/10        3       2576         1      0.06
PERLND  8          1976/06/20 12     3        918         1       1.5
PERLND  8          1976/07/15 12     3        918         1       1.5
PERLND  8          1976/08/25        3        334         1      0.20
PERLND  8          1976/12/02        3        334         1      0.12

PERLND  8          1977/04/15        3        334         1      0.20
PERLND  8          1977/05/07 12     3        334         1      0.26
PERLND  8          1977/05/07 12     3        918         1       2.0
PERLND  8          1977/05/10 12     3       2716         2     0.625
PERLND  8          1977/05/19 12     3       2716         2      1.25
PERLND  8          1977/05/30 12     3       2716         2     0.625
PERLND  8          1977/06/10        3       2576         1      0.06
PERLND  8          1977/06/20 12     3        918         1       1.5
PERLND  8          1977/07/13 12     3        918         1       1.5
PERLND  8          1977/08/24        3        334         1      0.20
PERLND  8          1977/12/01        3        334         1      0.12

PERLND  8          1978/04/15        3        334         1      0.20
PERLND  8          1978/05/05 12     3        334         1      0.26
PERLND  8          1978/05/05 12     3        918         1       2.0
PERLND  8          1978/05/10 12     3       2716         2     0.625
PERLND  8          1978/05/20 12     3       2716         2      1.25
PERLND  8          1978/05/30 12     3       2716         2     0.625
PERLND  8          1978/06/10        3       2576         1      0.06
PERLND  8          1978/06/18 12     3        918         1       1.5
PERLND  8          1978/07/15 12     3        918         1       1.5
PERLND  8          1978/08/23        3        334         1      0.20
PERLND  8          1978/12/01        3        334         1      0.12

INCREASE INFILT DUE TO THAWED GROUND      ***   (UNITS ARE IN/IVL)
PERLND  9          1974/04/10        3        334         1      0.30
REDUCE INFILT FOR FROZEN GROUND           ***
PERLND  9          1974/12/05        3        334         1      0.16
```

```
  PERLND  9         1975/04/10         3       334          1      0.30
  PERLND  9         1975/12/05         3       334          1      0.16

  PERLND  9         1976/04/10         3       334          1      0.30
  PERLND  9         1976/12/06         3       334          1      0.16

  PERLND  9         1977/04/10         3       334          1      0.30
  PERLND  9         1977/12/05         3       334          1      0.16

  PERLND  9         1978/04/10         3       334          1      0.30
  PERLND  9         1978/12/05         3       334          1      0.16
END SPEC-ACTIONS

PERLND

  ACTIVITY
    <PLS >          ACTIVE SECTIONS (1=ACTIVE; 0=INACTIVE)   ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC  ***
    1    2    0    1    1    1                   1    1
    3         0    1    1    1
    4    5    0    1    1    1                   1    1
    6         0    1    1    1
    7    8    0    1    1    1                   1    1
    9         0    1    1    1
  END ACTIVITY

  PRINT-INFO
    <PLS >          PRINT FLAGS                               ***      PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC        ***
    1    9         4    4    4                   4    4                      12
  END PRINT-INFO

  GEN-INFO
    <PLS >                          UNIT SYSTEM                      ***
    # -  #                NAME NBLK USER   IN  OUT ENGL METR         ***
    1      BEANS                   1    1    1    1   51    0
    2      CORN                    1    1    1    1   52    0
    3      OTHER                   1    1    1    1   53    0
    4      BEANS                   1    1    1    1   54    0
    5      CORN                    1    1    1    1   55    0
    6      OTHER                   1    1    1    1   56    0
    7      BEANS                   1    1    1    1   57    0
    8      CORN                    1    1    1    1   58    0
    9      OTHER                   1    1    1    1   59    0
  END GEN-INFO

  SECTION SNOW  ***

  ICE-FLAG
    <PLS >  0= ICE FORMATION NOT SIMULATED; 1= SIMULATED  ***
    # -  #ICEFG                                           ***
    1    9    1
  END ICE-FLAG

  SNOW-PARM1
    <PLS >  SNOW INPUT INFO: PART 1                                ***
    # -  #       LAT     MELEV     SHADE    SNOWCF    COVIND       ***
    1            42.      925.       0.0      1.45       0.5
    2            42.      925.       0.0      1.45       0.5
    3            42.      925.       0.0      1.45       0.5
    4           42.5     1110.       0.0      1.45       0.5
    5           42.5     1110.       0.0      1.45       0.5
    6           42.5     1110.       0.0      1.45       0.5
    7            43.     1225.       0.0      1.45       0.5
    8            43.     1225.       0.0      1.45       0.5
    9            43.     1225.       0.0      1.45       0.5
  END SNOW-PARM1

  SNOW-PARM2
    <PLS >  SNOW INPUT INFO: PART 2                                      ***
    # -  #     RDCSN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT   ***
    1           0.12       32.      0.05       0.5      0.08    0.0001
    2           0.12       32.      0.05       0.5      0.08    0.0001
    3           0.12       32.      0.05       0.5      0.08    0.0001
    4           0.12       32.      0.05       0.5      0.08    0.0001
    5           0.12       32.      0.05       0.5      0.08    0.0001
    6           0.12       32.      0.05       0.5      0.08    0.0001
    7           0.12       32.      0.05       0.5      0.08    0.0001
    8           0.12       32.      0.05       0.5      0.08    0.0001
    9           0.12       32.      0.05       0.5      0.08    0.0001
```

```
END SNOW-PARM2

SNOW-INIT1
  <PLS >  INITIAL SNOW CONDITIONS: PART 1                                   ***
  # -  #  PACKSNOW   PACKICE PACKWATER    RDENPF      DULL    PAKTMP        ***
  1    9       4.0       0.0       0.0       0.2       0.0       32.
END SNOW-INIT1

SNOW-INIT2
  <PLS >  INITIAL SNOW CONDITIONS: PART 2    ***
  # -  #    COVINX    XLNMLT    SKYCLR       ***
  1    9      0.01       0.0       1.0
END SNOW-INIT2

SECTION PWATER   ***

PWAT-PARM1
  <PLS >  PWATER VARIABLE MONT4LY PARAMETER VALUE FLAGS  ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
  1    9    1    0    0    1    1    1    0    0    1
END PWAT-PARM1

PWAT-PARM2
  <PLS > ***  PWATER INPUT INFO: PART 2 (PART 1 ONLY FLAGS)
  **** INPUT INFILT VALUES ARE FOR FROZEN GROUND ***
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1          0.000       7.0     0.040      300.     0.050       0.3      0.98
  2          0.000       7.0     0.040      300.     0.050       0.3      0.98
  3          0.010       8.0     0.060      300.     0.050       0.3      0.98
  4          0.000       7.0     0.050      320.     0.020       0.3      0.98
  5          0.000       7.0     0.050      320.     0.020       0.3      0.98
  6          0.010       8.0     0.070      320.     0.020       0.3      0.98
  7          0.000       8.0     0.060      350.     0.010       0.5      0.98
  8          0.000       8.0     0.060      350.     0.010       0.5      0.98
  9          0.010       9.0     0.080      350.     0.010       0.5      0.98
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER INPUT INFO: PART 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1            40.       35.       2.0       2.0       0.0       0.0      0.03
  2            40.       35.       2.0       2.0       0.0       0.0      0.03
  3            40.       35.       2.0       2.0       0.0       0.0      0.03
  4            40.       35.       2.0       2.0       0.0       0.0      0.03
  5            40.       35.       2.0       2.0       0.0       0.0      0.03
  6            40.       35.       2.0       2.0       0.0       0.0      0.03
  7            40.       35.       2.0       2.0       .10       0.0      0.08
  8            40.       35.       2.0       2.0       .10       0.0      0.08
  9            40.       35.       2.0       2.0       .10       0.0      0.08
END PWAT-PARM3

PWAT-PARM4
  <PLS > *** PWATER INPUT INFO: PART 4
  # -  # *** CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
  1                     0.01       0.1       1.0      0.60
  2                     0.01       0.1       1.0      0.60
  3                     0.01       0.1       1.2      0.80
  4                     0.01       0.1       1.0      0.60
  5                     0.01       0.1       1.0      0.60
  6                     0.01       0.1       1.2      0.80
  7                     0.01       0.1       1.0      0.60
  8                     0.01       0.1       1.0      0.60
  9                     0.01       0.1       1.2      0.80
END PWAT-PARM4

MON-INTERCEP
  <PLS>    ONLY REQUIRED IF VCSFG=1 IN PWAT-PARM1                           ***
  # -  #   INTERCEPTION STORAGE CAPACITY AT START OF EACH MONTH             ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC       ***
  1       0.03 0.03 0.03 0.03 0.01 0.01 0.08 0.16 0.18 0.14 0.03 0.03
  2       0.03 0.03 0.03 0.03 0.01 0.03 0.10 0.16 0.18 0.14 0.03 0.03
  3       0.06 0.06 0.06 0.07 0.07 0.08 0.10 0.10 0.10 0.10 0.07 0.06
  4       0.03 0.03 0.03 0.03 0.01 0.01 0.08 0.16 0.18 0.14 0.03 0.03
  5       0.03 0.03 0.03 0.03 0.01 0.03 0.10 0.16 0.18 0.14 0.03 0.03
  6       0.06 0.06 0.06 0.07 0.07 0.08 0.10 0.10 0.10 0.10 0.07 0.06
  7       0.03 0.03 0.03 0.03 0.01 0.01 0.08 0.16 0.18 0.14 0.03 0.03
  8       0.03 0.03 0.03 0.03 0.01 0.03 0.10 0.16 0.18 0.14 0.03 0.03
  9       0.06 0.06 0.06 0.07 0.07 0.08 0.10 0.10 0.10 0.10 0.07 0.06
END MON-INTERCEP
```

```
MON-UZSN
  <PLS>    ONLY REQUIRED IF VUZFG=1 IN PWAT-PARM1                         ***
  # -  #    UPPER ZONE STORAGE AT START OF EACH MONTH                      ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC     ***
  1        0.3  0.3  0.3  0.3  0.9  0.5  0.5  0.7  0.7  0.7  0.5  0.4
  2        0.3  0.3  0.3  0.3  0.8  0.4  0.4  0.7  0.7  0.7  0.5  0.4
  3        0.6  0.6  0.6  0.8  0.8  0.9  0.9  0.9  0.9  0.9  0.7  0.5
  4        0.4  0.4  0.4  0.4  1.3  0.8  0.8  1.0  1.0  1.0  0.8  0.6
  5        0.4  0.4  0.4  0.4  1.1  0.7  0.7  0.9  0.9  0.9  0.7  0.6
  6        0.8  0.8  0.8  0.8  1.1  1.3  1.3  1.3  1.3  1.3  1.0  0.8
  7        0.4  0.4  0.4  0.4  1.6  1.1  1.1  1.3  1.3  1.3  1.1  0.9
  8        0.4  0.4  0.4  0.4  1.4  1.0  1.0  1.2  1.2  1.2  1.0  0.9
  9        0.8  0.8  0.8  0.8  1.4  1.6  1.6  1.6  1.6  1.6  1.3  1.1
END MON-UZSN

MON-MANNING
  <PLS >   ONLY REQUIRED IF VNNFG=1 IN PWAT-PARM1                         ***
  # -  #   MANNING'S N FOR OVERLAND FLOW AT START OF EACH MONTH           ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC     ***
  1       0.25 0.25 0.25 0.25 0.25 0.15 0.15 0.20 0.22 0.25 0.25 0.25
  2       0.25 0.25 0.25 0.25 0.25 0.15 0.15 0.20 0.22 0.25 0.25 0.25
  3       0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30
  4       0.25 0.25 0.25 0.25 0.25 0.15 0.15 0.20 0.22 0.25 0.25 0.25
  5       0.25 0.25 0.25 0.25 0.25 0.15 0.15 0.20 0.22 0.25 0.25 0.25
  6       0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30
  7       0.25 0.25 0.25 0.25 0.25 0.15 0.15 0.20 0.22 0.25 0.25 0.25
  8       0.25 0.25 0.25 0.25 0.25 0.15 0.15 0.20 0.22 0.25 0.25 0.25
  9       0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.30
END MON-MANNING

MON-LZETPARM
  <PLS >   ONLY REQUIRED IF VLEFG=1 IN PWAT-PARM1                               ***
  # -  #   LOWER ZONE ET PARAMETER AT START OF EACH MONTH                       ***
           JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC           ***
  1       0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  2       0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  3       0.25 0.25 0.25 0.25 0.30 0.35 0.40 0.40 0.45 0.35 0.30 0.25
  4       0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  5       0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  6       0.25 0.25 0.25 0.25 0.30 0.35 0.40 0.40 0.45 0.35 0.30 0.25
  7       0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  8       0.20 0.20 0.20 0.23 0.23 0.25 0.60 0.80 0.75 0.50 0.30 0.20
  9       0.25 0.25 0.25 0.25 0.30 0.35 0.40 0.40 0.45 0.35 0.30 0.25
END MON-LZETPARM

PWAT-STATE1
  <PLS > *** INITIAL CONDITIONS AT START OF SIMULATION
  # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  1            0.0       0.0       0.8       0.0       8.0      0.45       0.9
  2            0.0       0.0       0.8       0.0       8.0      0.45       0.9
  3            0.0       0.0       2.0       0.0       9.0      0.50       1.0
  4            0.0       0.0       0.5       0.0       8.0      0.30       0.6
  5            0.0       0.0       0.5       0.0       8.0      0.30       0.6
  6            0.0       0.0       1.0       0.0       9.0       0.4       0.8
  7            0.0       0.0       0.5       0.0       7.5      0.20       0.4
  8            0.0       0.0       0.5       0.0       7.5      0.20       0.4
  9            0.0       0.0       1.0       0.0       8.5       0.4       0.8
END PWAT-STATE1

SECTION SEDMNT   ***

SED-PARM1
  <PLS > ***
  # -  #  CRV VSIV SDOP ***
  1    9    1    0    1
END SED-PARM1

SED-PARM2
  <PLS > ***
  # -  #        SMPF      KRER      JRER     AFFIX     COVER      NVSI ***
  1              1.0       .45       2.2      .030       1.0       0.0
  2              1.0       .45       2.2      .030       1.0       0.0
  3              1.0       .40       2.2      .003       1.0       0.0
  4              1.0       .45       2.2      .030       1.0       0.0
  5              1.0       .45       2.2      .030       1.0       0.0
  6              1.0       .40       2.2      .003       1.0       0.0
  7              1.0       .40       2.2      .030       1.0       0.0
  8              1.0       .40       2.2      .030       1.0       0.0
  9              1.0       .35       2.2      .003       1.0       0.0
END SED-PARM2
```

```
SED-PARM3
  <PLS > ***
  # -  #       KSER       JSER      KGER      JGER ***
  1           3.0        2.2       0.0       1.0
  2           2.0        2.0       0.0       1.0
  3           1.0        2.0       0.0       1.0
  4           3.0        2.2       0.0       1.0
  5           2.0        2.0       0.0       1.0
  6           1.0        2.0       0.0       1.0
  7           2.5        2.2       0.0       1.0
  8           1.8        2.0       0.0       1.0
  9           0.5        2.0       0.0       1.0
END SED-PARM3

MON-COVER
  <PLS >  MONTHLY VALUES FOR EROSION-RELATED LAND COVER  ***
  # -  #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC ***
  1       .17  .13  .09  .06  .01  .03  .43  .67  .77  .61  .26  .21
  2       .25  .22  .20  .18  .03  .08  .40  .70  .62  .51  .38  .29
  3       .90  .90  .90  .90  .90  .90  .90  .90  .90  .90  .90  .90
  4       .17  .13  .09  .06  .01  .03  .43  .67  .77  .61  .26  .21
  5       .25  .22  .20  .18  .03  .08  .40  .70  .62  .51  .38  .29
  6       .90  .90  .90  .90  .90  .90  .90  .90  .90  .90  .90  .90
  7       .17  .13  .09  .06  .01  .03  .43  .67  .77  .61  .26  .21
  8       .25  .22  .20  .18  .03  .08  .40  .70  .62  .51  .38  .29
  9       .90  .90  .90  .90  .90  .90  .90  .90  .90  .90  .90  .90
END MON-COVER

SED-STOR
  <PLS >  DETACHED SEDIMENT STORAGE TONS/ACRE  ***
  # -  #    BLOCK1      BLK2      BLK3      BLK4      BLK5  ***
  1            0.2
  2            0.2
  3            0.1
  4            0.2
  5            0.2
  6            0.1
  7            0.2
  8            0.2
  9            0.1
END SED-STOR

SECTION MSTLAY   ***

MST-PARM
  <PLS >       SLMPF       ULPF       LLPF  ***
  # -  #                                    ***
  1             0.7        5.0        1.5
  2             0.7        5.0        1.5
  3             0.5        5.0        1.5
  4             0.7        5.0        1.5
  5             0.7        5.0        1.5
  6             0.5        5.0        1.5
  7             0.7        5.0        1.5
  8             0.7        5.0        1.5
  9             0.5        5.0        1.5
END MST-PARM

MST-TOPSTOR    INITIAL MOISTURE STORAGES DEFAULTED TO ZERO ***
MST-TOPFLX     INITIAL MOISTURE FLUXES   DEFAULTED TO ZERO ***

SECTION PEST   ***

PEST-FLAGS
  <PLS >  OPTIONS FOR SIMULATION OF UP TO 3 DIFFERENT PESTICIDES ***
  # -  # NPST MAX ITERATIONS ADSORP OPTION                       ***
              PST1 PST2 PST3 PST1 PST2 PST3                      ***
  1    2    1   20              2
  4    5    1   20              2
  7    8    1   20              2
END PEST-FLAGS

SOIL-DATA
  <PLS >  SOIL LAYER DEPTHS AND BULK DENSITIES   ***
  # -  #             DEPTHS (IN)                  BULK DENSITY (LB/FT3)    ***
         SURFACE   UPPER   LOWER GROUNDW SURFACE   UPPER   LOWER GROUNDW ***
  1    2    0.25    5.71   41.30     60.    62.4    79.2    81.7    85.5
  4    5    0.25    5.71   41.30     60.    62.4    79.2    81.7    85.5
  7    8    0.25    5.71   41.30     60.    62.4    79.2    81.7    85.5
```

```
END SOIL-DATA

  ***    PESTICIDE NO. 1  -  ALACHLOR   ***

PEST-ID
  <PLS >                         ***
  #  -  #      PESTICIDE NAME  ***
  1    2       ALACHLOR
  4    5       ALACHLOR
  7    8       ALACHLOR
END PEST-ID

PEST-CMAX
  <PLS >  ONLY USED IF ADOPFG=2 OR 3 IN PEST-FLAGS   ***
  #  -  #   CMAX                                     ***
           (PPM)                                     ***
  1    2     242.
  4    5     242.
  7    8     242.
END PEST-CMAX

PEST-SVALPM       SURFACE LAYER
  <PLS >  ONLY USED IF ADOPFG=2 (SINGLE VALUE FREUNDLICH) IN PEST-FLAGS  ***
  #  -  #      XFIX        K1         N1                                 ***
             (PPM)                                                       ***
  1    2        0.0        4.        1.4
  4    5        0.0        4.        1.4
  7    8        0.0        4.        1.4
END PEST-SVALPM

PEST-SVALPM       UPPER LAYER
  <PLS >  ONLY USED IF ADOPFG=2 (SINGLE VALUE FREUNDLICH) IN PEST-FLAGS  ***
  #  -  #      XFIX        K1         N1                                 ***
             (PPM)                                                       ***
  1    2        0.0        4.        1.4
  4    5        0.0        4.        1.4
  7    8        0.0        4.        1.4
END PEST-SVALPM

PEST-SVALPM       LOWER LAYER
  <PLS >  ONLY USED IF ADOPFG=2 (SINGLE VALUE FREUNDLICH) IN PEST-FLAGS  ***
  #  -  #      XFIX        K1         N1                                 ***
             (PPM)                                                       ***
  1    2        0.0        3.        1.4
  4    5        0.0        3.        1.4
  7    8        0.0        3.        1.4
END PEST-SVALPM

PEST-SVALPM       GROUNDWATER LAYER
  <PLS >  ONLY USED IF ADOPFG=2 (SINGLE VALUE FREUNDLICH) IN PEST-FLAGS  ***
  #  -  #      XFIX        K1         N1                                 ***
             (PPM)                                                       ***
  1    2        0.0        3.        1.4
  4    5        0.0        3.        1.4
  7    8        0.0        3.        1.4
END PEST-SVALPM

PEST-DEGRAD
  <PLS >  PESTICIDE DEGRADATION RATES (PER DAY)    ***
  #  -  #   SURFACE     UPPER      LOWER   GROUNDW  ***
  1    2      0.120     0.045       0.04      0.04
  4    5      0.120     0.045       0.04      0.04
  7    8      0.120     0.045       0.04      0.04
END PEST-DEGRAD

PEST-STOR1
  <PLS >  INITIAL PESTICIDE STORAGE IN SURFACE LAYER (LB/AC)  ***
  #  -  #   CRYSTAL  ADSORBED  SOLUTION                        ***
  1    2        0.0       0.0       0.0
  4    5        0.0       0.0       0.0
  7    8        0.0       0.0       0.0
END PEST-STOR1

PEST-STOR1
  <PLS >  INITIAL PESTICIDE STORAGE IN UPPER LAYER (LB/AC)  ***
  #  -  #   CRYSTAL  ADSORBED  SOLUTION                        ***
  1    2        0.0       0.0       0.0
  4    5        0.0       0.0       0.0
  7    8        0.0       0.0       0.0
END PEST-STOR1
```

```
  PEST-STOR1
    <PLS >  LOWER LAYER STORAGE                                   ***
    # -  #   CRYSTAL  ADSORBED  SOLUTION                            ***
    1   2       0.0       0.0       0.0
    4   5       0.0       0.0       0.0
    7   8       0.0       0.0       0.0
  END PEST-STOR1

  PEST-STOR1
    <PLS >  GROUNDWATER STORAGE OF PESTICIDE                      ***
    # -  #   CRYSTAL  ADSORBED  SOLUTION                            ***
    1   2       0.0       0.0       0.0
    4   5       0.0       0.0       0.0
    7   8       0.0       0.0       0.0
  END PEST-STOR1

END PERLND

RCHRES

  ACTIVITY
    RCHRES  ACTIVE SECTIONS (1=ACTIVE; 0=INACTIVE)   ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG   ***
    1   13    1    1    0    0    1    1    0    0    0    0
  END ACTIVITY

  PRINT-INFO
    RCHRES  PRINTOUT LEVEL FLAGS   ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR   ***
    1         4    4    0    0    4    4    0    0    0    0         12
    2    6    5    5    0    0    5    5    0    0    0    0         12
    7         4    4    0    0    4    4    0    0    0    0         12
    8   12    5    5    0    0    5    5    0    0    0    0         12
   13         4    4    0    0    4    4    0    0    0    0         12
  END PRINT-INFO

  GEN-INFO
    RCHRES<NAME                 >NEXIT< UNIT SYSTEM ><PRINTER >     ***
    # -  #                             UCI   IN  OUT ENGL METR LKFG ***
    1     HONEY CR TO MARENGO       1    1    1    1   71    0    0
    2     SALT CR TO HONEY CR       1    1    1    1   72    0    0
    3     RCHLD CR TO SALT CR       1    1    1    1   73    0    0
    4     DEER CR TO RCHLD CR       1    1    1    1   74    0    0
    5     SUGAR CR TO DEER CR       1    1    1    1   75    0    0
    6     MARSHALLT TO SUGAR        1    1    1    1   76    0    0
    7     HONEY CR TO MARSHL        1    1    1    1   77    0    0
    8     S. FORK TO HONEY CR       1    1    1    1   78    0    0
    9     MIDPOINT TO S. FORK       1    1    1    1   79    0    0
   10     IOWA FALLS TO MIDPT       1    1    1    1   80    0    0
   11     UNNAMED TO IA. FALL       1    1    1    1   81    0    0
   12     ROWAN TO UNNAMED          1    1    1    1   82    0    0
   13     BELMOND TO ROWAN          1    1    1    1   83    0    0
  END GEN-INFO

  SECTION HYDR   ***

  HYDR-PARM1
    RCHRES FLAGS FOR HYDR SECTION ***
    # -  #  VC A1 A2 A3  < F(VOL) COL# > *** <G(T) ELEMENT#>      <COMBINE FUNCT>
    1   13  0  1  1  1     4  0  0  0  0       0  0  0  0  0
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES CHANNEL NETWORK INFO ***
    # -  # FTABLE NO  LEN (MI)   DELTA H   DATUM H        KS ***  DB50
    1         1      10.8      14.8                 0.5     0.014
    2         2      10.1      16.0                 0.5     0.014
    3         3      12.5      21.1                 0.5     0.014
    4         4      16.2      25.7                 0.5     0.014
    5         5      18.5      27.3                 0.5     0.014
    6         6      15.1      26.3                 0.5     0.014
    7         7      10.4      25.8                 0.5     0.014
    8         8      13.9      32.3                 0.5     0.014
    9         9      17.6      51.1                 0.5     0.014
   10        10      17.6      64.1                 0.5     0.014
   11        11      17.9      62.4                 0.5     0.014
   12        12      16.4      26.8                 0.5     0.014
```

```
 13             13       9.3      12.8                  0.5     0.014
END HYDR-PARM2

HYDR-INIT
  RCHRES INITIAL CONDITIONS FOR HYDR ***
       ***    1/1/74 FLOW: MARENGO 1000 CFS
  # -  #VOL(AC-FT) PAIR OF COLS FOR F(VOL)    INITIAL G(T) COMPONENT    ***
                    EX1  EX2  EX3  EX4  EX5  EX1  EX2  EX3  EX4  EX5    ***
  1          1016.  4.0
  2           716.  4.0
  3           776.  4.0
  4           974.  4.0
  5          1066.  4.0
  6           783.  4.0
  7           397.  4.0
  8           472.  4.0
  9           432.  4.0
 10           376.  4.0
 11           347.  4.0
 12           370.  4.0
 13           206.  4.0
END HYDR-INIT

SECTION SEDTRN ***

SANDFG
  RCHRES       ***
  #    # SDFG ***
  1   13    1
END SANDFG

SED-GENPARM
  RCHRES    BEDWID    BEDWRN       POR ***
  #    #      (ft)      (ft)           ***
  1           150.       15.
  2           140.       15.
  3           130.       15.
  4           125.       15.
  5           110.       15.
  6           110.       15.
  7           100.       15.
  8            95.       15.
  9            95.       10.
 10            90.       10.
 11            84.       10.
 12            85.       10.
 13            85.       10.
END SED-GENPARM

SAND-PM
  RCHRES          D         W       RHO     KSAND    EXPSND ***
  #    #       (in)  (in/sec)                                ***
  1   13       .014       2.5      2.65
END SAND-PM

    SILT PARAMETERS    ***
SILT-CLAY-PM
  RCHRES          D         W       RHO     TAUCD     TAUCS         M ***
  #    #       (in)  (in/sec)            (lb/ft2)  (lb/ft2) (lb/ft2d) ***
  1   13     .00063     .0066       2.2      0.05      0.15       3.0
END SILT-CLAY-PM

    CLAY PARAMETERS    ***
SILT-CLAY-PM
  RCHRES          D         W       RHO     TAUCD     TAUCS         M ***
  #    #       (in)  (in/sec)            (lb/ft2)  (lb/ft2) (lb/ft2d) ***
  1   13    .000055   .000034       2.0      0.04      0.12       6.5
END SILT-CLAY-PM

SSED-INIT
  RCHRES      Suspended sed concs (mg/l) ***
  #    #       SAND      SILT      CLAY ***
  1   13        0.0       16.       24.
END SSED-INIT

BED-INIT
  RCHRES    BEDDEP  Initial bed composition       ***
  #    #      (ft)      Sand      Silt      Clay ***
  1            10.      0.60      0.20      0.20
  2             9.      0.60      0.20      0.20
```

```
    3            8.       0.60      0.20      0.20
    4            8.       0.50      0.25      0.25
    5            7.       0.50      0.25      0.25
    6            7.       0.50      0.25      0.25
    7            6.       0.50      0.25      0.25
    8            5.       0.50      0.25      0.25
    9            5.       0.50      0.25      0.25
   10            4.       0.50      0.25      0.25
   11            4.       0.50      0.25      0.25
   12            3.       0.50      0.25      0.25
   13            3.       0.50      0.25      0.25
  END BED-INIT

  SECTION GQUAL ###

  GQ-GENDATA
    RCHRES        GQUAL General Info                 ###
    #    #  HQL TPFG PHFG ROFG CDFG SDFG PYFG  LAT ###
    1   13    1    1
  END GQ-GENDATA

  QUAL #1 - ALACHLOR  ###

  GQ-QALDATA
    RCHRES  ###
    #    #  ###            GQID  DQAL(mg)    CONCID      CONV     QTYID
    1   13             ALACHLOR       0.0        mg 1.6017E+4        lb
  END GQ-QALDATA

  GQ-QALFG
    RCHRES    First set of flags for a qual   ###
    #    # HDRL OXID PHOT VOLT BIOD  GEN SDAS ###
    1   13                             1    1
  END GQ-QALFG

  GQ-GENDECAY
    RCHRES     FSTDEC      THFST ###
    #    #     (/day)            ###
    1   13     0.080       1.07
  END GQ-GENDECAY

  GQ-SEDDECAY
    RCHRES      KSUSP    THSUSP      KBED     THBED ###
    #    #     (/day)              (/day)           ###
    1   13      0.100      1.07     0.120      1.07
  END GQ-SEDDECAY

  GQ-KD
    RCHRES     Partition coefficients (l/mg)                           ###
    #    #      ADPM1     ADPM2     ADPM3     ADPM4     ADPM5     ADPM6 ###
    1   13     2.0E-6    1.0E-5    5.0E-5    1.0E-5    5.0E-5    1.0E-4
  END GQ-KD

  GQ-ADRATE
    RCHRES     Ads/Des rate parameters (/day)                          ###
    #    #      ADPM1     ADPM2     ADPM3     ADPM4     ADPM5     ADPM6 ###
    1   13        8.0       8.0       8.0       .03       .03       .03
  END GQ-ADRATE

  GQ-ADTHETA
    RCHRES     Ads/Des temperature correction parameters               ###
    #    #      ADPM1     ADPM2     ADPM3     ADPM4     ADPM5     ADPM6 ###
    1   13        1.0       1.0       1.0       1.0       1.0       1.0
  END GQ-ADTHETA

  GQ-SEDCONC
    RCHRES     Initial concentrations on sediments (mg/mg)            ###
    #    #      SQAL1     SQAL2     SQAL3     SQAL4     SQAL5     SQAL6 ###
    1   13        0.0       0.0       0.0       0.0       0.0       0.0
  END GQ-SEDCONC

END RCHRES


FTABLES

  FTABLE      1
```

```
ROWS COLS                                         ***
  17     4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       4.0     250.0     579.9     270.0      26.0
       5.0     281.5     848.3     710.0      14.4
       6.0     294.5    1137.6    1210.0      11.4
       7.0     302.4    1437.4    1721.0      10.1
       8.0     307.6    1741.1    2258.0       9.3
       9.0     314.2    2048.7    2840.0       8.8
      10.0     322.0    2366.8    3490.0       8.2
      11.0     360.0    2700.7    4249.0       7.7
      12.0     435.9    3101.2    5120.0       7.3
      13.0     455.6    3543.7    6300.0       6.8
      14.0     484.4    4296.4    8206.0       6.3
      15.0     517.1    5364.6   10900.0       6.0
      16.0     549.8    6837.4   14730.0       5.6
      17.0     589.1    8960.7   20330.0       5.3
      18.0     628.4   11497.7   27490.0       5.1
      19.0     667.6   12188.9   36500.0       4.0
 END FTABLE  1

 FTABLE       2
ROWS COLS ***
  13     4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.517   184.248  267.8384  233.5109     832.7
     3.033   199.551  558.8862  753.5811     538.4
     4.550   214.854  873.1438 1507.3840     420.5
     6.067   230.158 1210.6110 2479.9080     354.4
     7.583   245.461 1571.2870 3666.0350     311.2
     9.100   260.763 1955.1730 5065.1170     280.2
    12.133   291.370 2792.5750 8510.6010     238.2
    15.167   321.975 3722.815012844.6200     210.4
    18.200   352.581 4745.890018105.8600     190.3
    24.267   847.719 8386.800034735.1900     175.3
    30.333  1342.85715031.540059649.6300     182.9
    36.400  1837.99524680.120095395.1800     187.8
 END FTABLE  2

 FTABLE       3
ROWS COLS ***
  13     4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.433   210.732  288.9285  198.0271    1059.3
     2.867   229.040  604.0977  639.6987     685.6
     4.300   247.348  945.5090 1280.9470     535.9
     5.733   265.656 1313.1630 2109.7010     451.9
     7.167   283.964 1707.0570 3122.2200     396.9
     8.600   302.272 2127.1930 4318.5110     357.6
    11.467   338.889 3046.1910 7271.6710     304.1
    14.333   375.505 4070.156010996.9500     268.7
    17.200   412.120 5199.078015530.5400     243.0
    22.933   991.242 9222.035029932.8100     223.7
    28.667  1570.36616565.300051548.8900     233.3
    34.400  2149.48927228.850082592.3700     239.3
 END FTABLE  3

 FTABLE       4
ROWS COLS ***
  13     4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.383   262.472  347.2415  191.2105    1318.4
     2.767   285.382  726.1736  617.7407     853.4
     4.150   308.291 1136.7960 1237.1120     667.1
     5.533   331.200 1579.1110 2037.7360     562.6
     6.917   354.109 2053.1160 3016.0610     494.2
     8.300   377.018 2558.8100 4172.1520     445.3
    11.067   422.836 3665.2770 7026.7810     378.7
    13.833   468.654 4898.503010628.8100     334.6
    16.600   514.472 6258.488015013.5400     302.6
    22.133  1238.83211109.270028952.0300     278.6
    27.667  1963.19519968.200049882.5400     290.6
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   33.200  2687.55732835.260079952.6200     298.2
 END FTABLE  4

 FTABLE      5
ROWS COLS                                       ***
  15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       1.0     103.2      51.6      10.0      62.5
       1.8     188.4     170.4      50.0      41.3
       2.3     246.7     287.0     100.0      34.8
       3.5     347.6     634.6     300.0      25.7
       4.2     374.5     888.0     500.0      21.5
       5.5     405.9    1390.3    1000.0      16.9
       7.3     430.5    2159.5    2000.0      13.1
      10.0     468.7    3374.8    4000.0      10.2
      12.2     491.1    4408.6    6000.0       8.9
      13.9     515.8    5274.2    8000.0       8.0
      15.4     531.5    6070.2   10000.0       7.4
      18.1     531.5    7491.9   14000.0       6.5
      20.5     531.5    8902.4   18000.0       6.0
      23.0     531.5   10090.0   22000.0       5.6
 END FTABLE  5

 FTABLE      6
ROWS COLS                                       ***
  16    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       1.0      82.4      38.4      10.0      46.6
       1.7     150.1     130.0      50.0      31.5
       2.3     195.8     219.6     100.0      26.6
       3.3     265.4     479.5     300.0      19.4
       4.1     289.2     675.4     500.0      16.4
       5.3     305.7    1046.9    1000.0      12.7
       6.3     316.6    1352.6    1500.0      10.9
       7.1     327.6    1625.3    2000.0       9.9
       9.9     353.2    2549.6    4000.0       7.7
      12.0     375.2    3316.5    6000.0       6.7
      13.7     395.3    3966.3    8000.0       6.0
      15.2     395.3    4564.8   10000.0       5.5
      16.6     395.3    5117.5   14000.0       4.4
      18.0     395.3    5673.9   18000.0       3.8
      19.4     395.3    6223.0   22000.0       3.4
 END FTABLE  6

 FTABLE      7
ROWS COLS                                       ***
  11    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       1.0     181.5     110.9     163.8       8.2
       2.0     277.3     344.1     460.7       9.0
       4.0     332.8     934.1    1389.0       8.2
       6.0     385.7    1651.4    2660.0       7.5
       8.0     534.5    2622.0    4197.0       7.6
      10.0     557.2    3706.2    6718.0       6.7
      12.0     584.9    4853.3   10880.0       5.4
      13.0     611.4    5798.8   14860.0       4.7
      14.0     642.9    7563.6   20460.0       4.5
      33.3     642.9    20000.   65000.0       3.7
 END FTABLE  7

 FTABLE      8
ROWS COLS                                       ***
  19    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       0.6     160.1      45.5      10.0      55.2
       1.4     203.9     195.4     100.0      23.7
       2.3     217.3     385.8     300.0      15.6
       2.9     227.5     534.1     500.0      13.0
       4.2     246.0     837.4    1000.0      10.2
       5.2     259.5    1091.8    1500.0       8.8
       6.1     271.3    1320.9    2000.0       8.0
       6.9     283.1    1536.6    2500.0       7.5
       7.6     293.2    1737.1    3000.0       7.0
       8.8     310.0    2114.5    4000.0       6.4
      10.8     350.4    2783,4    6000.0       5.6
      12.6     382.5    3410.0    8000.0       5.2
      13.9     384.1    3930.8   10000.0       4.8
      15.2     384.1    4407.6   12000.0       4.5
      16.3     384.1    4852.4   14000.0       4.2
      17.4     384.1    5305.7   16000.0       4.0
      18.5     384.1    5676.3   18000.0       3.8
      42.8     384.1    15000.   52000.0       3.5
  END FTABLE  8

  FTABLE       9
 ROWS COLS                                        ***
   19    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       0.5     192.0      51.2      10.0      62.1
       1.3     258.1     230.4     100.0      27.9
       2.2     273.1     456.5     300.0      18.5
       2.8     283.7     631.5     500.0      15.3
       4.0     305.1     983.5    1000.0      11.9
       4.9     322.1    1284.3    1500.0      10.4
       5.7     337.1    1555.2    2000.0       9.4
       7.1     362.7    2039.5    3000.0       8.2
       8.3     384.0    2483.2    4000.0       7.2
       9.3     405.3    2888.5    5000.0       7.0
      10.3     428.8    3266.1    6000.0       6.6
      11.1     448.0    3630.9    7000.0       6.3
      11.9     467.2    3989.3    8000.0       6.0
      12.6     486.4    4339.2    9000.0       5.8
      13.2     486.4    4531.2   10000.0       5.5
      13.8     486.4    4925.9   11000.0       5.4
      14.4     486.4    5203.2   12000.0       5.3
      34.5     486.4    15000.   45000.0       4.0
  END FTABLE  9

  FTABLE      10
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     0.967   221.156  203.8163  105.3339    1404.8
     1.933   241.778  427.5671  340.9438     910.5
     2.900   262.400  671.2532  684.1250     712.3
     3.867   283.022  934.8733 1129.0880     601.1
     4.833   303.644 1218.4290 1674.4200     528.3
     5.800   324.267 1521.9190 2320.6460     476.1
     7.733   365.511 2188.7030 3922.5970     405.1
     9.667   406.755 2935.2270 5953.2500     358.0
    11.600   448.000 3761.4890 8435.0070     323.8
    15.467   997.925 6556.945016461.7100     289.2
    19.333  1547.85011478.770028863.3700     288.7
    23.200  2097.77418526.940047091.1000     285.6
  END FTABLE 10

  FTABLE      11
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     0.850   196.357  159.0658   60.7026    1902.4
     1.700   214.800  333.8074  196.5158    1233.2
     2.550   233.242  524.2251  394.3945     965.0
     3.400   251.685  730.3184  651.0386     814.4
     4.250   270.127  952.0884  965.6660     715.8
     5.100   288.569 1189.5340 1338.6120     645.1
     6.800   325.454 1711.4540 2263.4980     548.9
     8.500   362.339 2296.0790 3436.4480     485.1
    10.200   399.224 2943.4050 4870.5540     438.7
    13.600   891.021 5136.8200 9513.9370     392.0
    17.000  1382.817 9002.332016694.9700     391.5
    20.400  1874.61314539.940027256.7500     387.3
  END FTABLE 11

  FTABLE      12
 ROWS COLS ***
```

```
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     0.875   186.364  155.4583   43.8048    2576.5
     1.750   203.757  326.1360  141.7904    1669.9
     2.625   221.151  512.0332  284.5178    1306.5
     3.500   238.545  713.1506  469.5835    1102.6
     4.375   255.939  929.4878  696.4016     969.0
     5.250   273.333 1161.0440  965.1946     873.3
     7.000   308.121 1669.8160 1631.5490     743.0
     8.750   342.909 2239.4680 2476.2790     656.6
    10.500   377.697 2869.9980 3508.7200     593.8
    14.000   841.534 5003.6480 6848.3780     530.4
    17.500  1305.372 8760.738012008.9400     529.6
    21.000  1769.21014141.250019594.5400     523.9
  END FTABLE 12

  FTABLE     13
 ROWS COLS                                         ***
   14    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       0.5      94.7      36.4      11.8      36.9
       1.0     112.7      89.4      48.8      22.0
       2.0     120.6     205.2     152.0      16.2
       3.0     130.8     331.4     308.0      13.0
       4.0     142.0     466.7     504.0      11.2
       5.0     151.0     613.2     744.0      10.0
       6.0     160.1     768.8    1020.0       9.1
       6.5     164.6     850.0    1220.0       8.4
       7.5     174.7    1090.1    1750.0       7.5
       8.5     186.0    1454.2    2580.0       6.8
       9.5     197.3    2014.4    3860.0       6.3
      10.5     214.2    2660.4    5500.0       5.9
      68.1     214.2    15000.    45000.       4.0
  END FTABLE 13

END FTABLES

DISPLY
  DISPLY-INFO1
    # -  # ***     TITLE                 TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YEND
    1    FLOW (IN) MARENGO (SIM)         SUM     0    3   50    1    4   61   12
    3    SED LD (LB/AC)MARENGO(SIM)      SUM     0    3   50    1    2   62   12
    5    FLOW (CFS) ROWAN (SIM)          AVER    0    3   50    1    1   63   12
    7    FLOW (CFS) MARSHLTWN (SIM)      AVER    0    3   50    1    1   64   12
    9    FLOW (CFS) MARENGO (SIM)        AVER    0    3   50    1    1   65   12
   11    SED WSHFF PLS1-BEANS(LB/AC)     SUM     0    3   50    1    4   66   12
   12    SED WSHFF PLS2-CORN(LB/AC)      SUM     0    3   50    1    4   66   12
   13    SED WSHFF PLS3-PAST.(LB/AC)     SUM     0    3   50    1    4   66   12
   14    SED WSHFF PLS4-BEANS(LB/AC)     SUM     0    3   50    1    4   66   12
   15    SED WSHFF PLS5-CORN(LB/AC)      SUM     0    3   50    1    4   66   12
   16    SED WSHFF PLS6-PAST.(LB/AC)     SUM     0    3   50    1    4   66   12
   17    SED WSHFF PLS7-BEANS(LB/AC)     SUM     0    3   50    1    4   66   12
   18    SED WSHFF PLS8-CORN(LB/AC)      SUM     0    3   50    1    4   66   12
   19    SED WSHFF PLS9-PAST.(LB/AC)     SUM     0    3   50    1    4   66   12
   20    SOL ALAC CONC(MG/L) MARSHLT     AVER    0    3   50    1    5   67   12
   21    SOL ALAC LOAD(LB/AC)MARSHLT     SUM     0    3   50    1    4   68   12
   22    SED ALAC CONC(PPM) MARSHLT      AVER    0    3   50    1    5   67   12
   23    SED ALAC LOAD(LB/AC)MARSHLT     SUM     0    3   50    1    4   68   12
   24    SOL ALAC CONC(MG/L) MARENGO     AVER    0    3   50    1    5   69   12
   25    SOL ALAC LOAD(LB/AC)MARENGO     SUM     0    3   50    1    4   70   12
   26    SED ALAC CONC(PPM) MARENGO      AVER    0    3   50    1    5   69   12
   27    SED ALAC LOAD(LB/AC)MARENGO     SUM     0    3   50    1    4   70   12
  END DISPLY-INFO1

END DISPLY

PLTGEN

  PLOTINFO
    #thru# FILE  NPT  NMN Labl  PYR PIVL ***
    1        31         2              12
    2        32         2              12
    3        33         2              12
    4        34         2              12
    5        35    2                   12
    6        36         2              12
    7      37        2              12
    8      38        2              12
  END PCOTINFO

  GEN-LABELS
    #thru#<----------------TITLE ----------------->***      <------Y AXIS------>
    1     FLOW: ROWAN                                       CFS
    2     FLOW: MARSHALLTOWN                                CFS
    3     FLOW: MARENGO                                     CFS
    4     SED LOAD: MARENGO                                 LB/AC
    5     SOLN ALAC CONC                                    MG/L
    6     SED ALAC CONC                                     PPM
    7     SOLN ALAC LOAD                                    LB/AC
    8     SED ALAC LOAD                                     LB/AC
  END GEN-LABELS

  SCALING
    #thru#      YMIN       YMAX     IVLIN ***
    1             0.      1500.       20.
    2             0.      5000.       20.
    3             0.     15000.       20.
    4             0.       200.       20.
    5             0.        0.1       20.
    6             0.        0.5       20.
    7             0.     0.0005       20.
    8             0.    0.00005       20.
  END SCALING

  CURV-DATA         (first curve)
    #thru#    < Curve label   > ***
    1         SIMULATED             10       8     1 AVER
    2         SIMULATED             10       8     1 AVER
    3         SIMULATED             10       8     1 AVER
    4         SIMULATED             10       8     1 SUM
    5         MARSHALLTOWN          10       8     1 AVER
    6         MARSHALLTOWN          10       8     1 AVER
    7         MARSHALLTOWN          10       8     1 SUM
    8         MARSHALLTOWN          10       8     1 SUM
  END CURV-DATA

  CURV-DATA         (second curve)
    #thru#    < Curve label   > ***
    1         OBSERVED              10       1     1 AVER
    2         OBSERVED              10       1     1 AVER
    3         OBSERVED              10       1     1 AVER
    4         OBSERVED              10       1     1 SUM
    5         MARENGO               10       1     1 AVER
    6         MARENGO               10       1     1 AVER
    7         MARENGO               10       1     1 SUM
    8         MARENGO               10       1     1 SUM
  END CURV-DATA

END PLTGEN


GENER
  OPCODE
    # TO #  OP-   ***
    1    2   19
  END OPCODE
END GENER


EXT SOURCES
<-VOLUME-> <MEMBER> <SS><SG><-MFACT--><TR> <TARGET VOLS-> <TGRP> <MEMBER--> ***
<NAME>   # <NAME> #                        <NAME>   #   #        <NAME> # # ***
TSS     39 PRECIP   ENGLZERO   1.03        PERLND   1   3 EXTNL  PREC
TSS    131 PRECIP   ENGLZERO   0.98        PERLND   4   6 EXTNL  PREC
TSS    132 PRECIP   ENGLZERO   0.95        PERLND   7   9 EXTNL  PREC
TSS    121 ARTEMP   ENGL       0.98   SAME PERLND   1   3 ATEMP  AIRTMP
TSS    123 ARTEMP   ENGL       0.92   SAME PERLND   4   6 ATEMP  AIRTMP
TSS    122 ARTEMP   ENGL       0.88   SAME PERLND   7   9 ATEMP  AIRTMP
TSS     41 EVAPOR   ENGL       0.7         PERLND   1   9 EXTNL  PETINP
TSS     42 WINDXX   ENGL                   PERLND   1   9 EXTNL  WINMOV
TSS     46 SOLRAD   ENGL                   PERLND   1   9 EXTNL  SOLRAD
TSS    124 DEWPNT   ENGL              SAME PERLND   1   3 EXTNL  DTMPG
TSS    126 DEWPNT   ENGL              SAME PERLND   4   6 EXTNL  DTMPG
TSS    125 DEWPNT   ENGL              SAME PERLND   7   9 EXTNL  DTMPG
TSS    121 ARTEMP   ENGL              SAME RCHRES   1   6 EXTNL  GATMP
TSS    123 ARTEMP   ENGL              SAME RCHRES   7  11 EXTNL  GATMP
TSS     122 ARTEMP   ENGL               SAME RCHRES  12  13 EXTNL  GATMP
TSS      41 EVAPOR   ENGL       0.7          RCHRES   1  13 EXTNL  POTEV
TSS      42 WIHDXX   ENGL                    RCHRES   1  13 EXTNL  WIND
TSS      46 SOLRAD   ENGL                    RCHRES   1  13 EXTNL  SOLRAD
TSS     124 DEWPNT   ENGL               SAME RCHRES   1   6 EXTNL  DEWTMP
TSS     126 DEWPNT   ENGL               SAME RCHRES   7  11 EXTNL  DEWTMP
TSS     125 DEWPNT   ENGL               SAME RCHRES  12  13 EXTNL  DEWTMP
TSS     134 WATEMP   METR                    RCHRES   1  13 HTRCH  TW
TSS     127 SEDMNT   ENGL          1.0  DIV  PLTGEN   4     INPUT  MEAN   2
TSS     136 STFLOW   ENGL          1.0  SAME PLTGEN   1     INPUT  MEAN   2
TSS     113 STFLOW   ENGL          1.0  SAME PLTGEN   2     INPUT  MEAN   2
TSS     119 STFLOW   ENGL          1.0  SAME PLTGEN   3     INPUT  MEAN   2
END EXT SOURCES

NETWORK
<-VOLUME-> <GRP-> <-MEMBER-><-MFACT--><TR> <TARGET VOLS-> <TGRP> <MEMBER--> ***
<NAME>   #        <NAME> # #                <NAME>   #    #         <NAME> # # ***
PERLND   7 PWATER PERO           7413.     RCHRES  13     INFLOW IVOL
PERLND   8 PWATER PERO          10770.     RCHRES  13     INFLOW IVOL
PERLND   9 PWATER PERO           4640.     RCHRES  13     INFLOW IVOL
PERLND   7 SEDMNT SOSED          8896.     RCHRES  13     INFLOW ISED   1
PERLND   7 SEDMNT SOSED         44480.     RCHRES  13     INFLOW ISED   2
PERLND   7 SEDMNT SOSED         35584.     RCHRES  13     INFLOW ISED   3
PERLND   8 SEDMNT SOSED         12928.     RCHRES  13     INFLOW ISED   1
PERLND   8 SEDMNT SOSED         64640.     RCHRES  13     INFLOW ISED   2
PERLND   8 SEDMNT SOSED         51712.     RCHRES  13     INFLOW ISED   3
PERLND   9 SEDMNT SOSED         33408.     RCHRES  13     INFLOW ISED   2
PERLND   9 SEDMNT SOSED         22272.     RCHRES  13     INFLOW ISED   3
PERLND   7 PEST   POPST  1      26688.     RCHRES  13     INFLOW IDQAL  1
PERLND   7 PEST   SOSDPS 1       3203.     RCHRES  13     INFLOW ISQAL  2 1
PERLND   7 PEST   SOSDPS 1      23485.     RCHRES  13     INFLOW ISQAL  3 1
PERLND   8 PEST   POPST  1      64640.     RCHRES  13     INFLOW IDQAL  1
PERLND   8 PEST   SOSDPS 1       7757.     RCHRES  13     INFLOW ISQAL  2 1
PERLND   8 PEST   SOSDPS 1      56883.     RCHRES  13     INFLOW ISQAL  3 1
RCHRES  13 ROFLOW                1.0       RCHRES  12     INFLOW
PERLND   7 PWATER PERO           2667.     RCHRES  12     INFLOW IVOL
PERLND   8 PWATER PERO           3787.     RCHRES  12     INFLOW IVOL
PERLND   9 PWATER PERO           1600.     RCHRES  12     INFLOW IVOL
PERLND   7 SEDMNT SOSED          3200.     RCHRES  12     INFLOW ISED   1
PERLND   7 SEDMNT SOSED         16000.     RCHRES  12     INFLOW ISED   2
PERLND   7 SEDMNT SOSED         12800.     RCHRES  12     INFLOW ISED   3
PERLND   8 SEDMNT SOSED          4544.     RCHRES  12     INFLOW ISED   1
PERLND   8 SEDMNT SOSED         22720.     RCHRES  12     INFLOW ISED   2
PERLND   8 SEDMNT SOSED         18176.     RCHRES  12     INFLOW ISED   3
PERLND   9 SEDMNT SOSED         11520.     RCHRES  12     INFLOW ISED   2
PERLND   9 SEDMNT SOSED          7680.     RCHRES  12     INFLOW ISED   3
PERLND   7 PEST   POPST  1       9600.     RCHRES  12     INFLOW IDQAL  1
PERLND   7 PEST   SOSDPS 1       1152.     RCHRES  12     INFLOW ISQAL  2 1
PERLND   7 PEST   SOSDPS 1       8448.     RCHRES  12     INFLOW ISQAL  3 1
PERLND   8 PEST   POPST  1      22720.     RCHRES  12     INFLOW IDQAL  1
PERLND   8 PEST   SOSDPS 1       2726.     RCHRES  12     INFLOW ISQAL  2 1
PERLND   8 PEST   SOSDPS 1      19994.     RCHRES  12     INFLOW ISQAL  3 1
RCHRES  12 ROFLOW                1.0       RCHRES  11     INFLOW
PERLND   4 PWATER PERO           1120.     RCHRES  11     INFLOW IVOL
PERLND   5 PWATER PERO           2027.     RCHRES  11     INFLOW IVOL
PERLND   6 PWATER PERO            960.     RCHRES  11     INFLOW IVOL
PERLND   4 SEDMNT SOSED          1344.     RCHRES  11     INFLOW ISED   1
PERLND   4 SEDMNT SOSED          6720.     RCHRES  11     INFLOW ISED   2
PERLND   4 SEDMNT SOSED          5376.     RCHRES  11     INFLOW ISED   3
PERLND   5 SEDMNT SOSED          2432.     RCHRES  11     INFLOW ISED   1
PERLND   5 SEDMNT SOSED         12160.     RCHRES  11     INFLOW ISED   2
PERLND   5 SEDMNT SOSED          9728.     RCHRES  11     INFLOW ISED   3
PERLND   6 SEDMNT SOSED          6912.     RCHRES  11     INFLOW ISED   2
PERLND   6 SEDMNT SOSED          4608.     RCHRES  11     INFLOW ISED   3
PERLND   4 PEST   POPST  1       4032.     RCHRES  11     INFLOW IDQAL  1
PERLND   4 PEST   SOSDPS 1        484.     RCHRES  11     INFLOW ISQAL  2 1
PERLND   4 PEST   SOSDPS 1       3548.     RCHRES  11     INFLOW ISQAL  3 1
PERLND   5 PEST   POPST  1      12160.     RCHRES  11     INFLOW IDQAL  1
PERLND   5 PEST   SOSDPS 1       1459.     RCHRES  11     INFLOW ISQAL  2 1
PERLND   5 PEST   SOSDPS 1      10701.     RCHRES  11     INFLOW ISQAL  3 1
RCHRES  11 ROFLOW                1.0       RCHRES  10     INFLOW
PERLND   4 PWATER PERO           1013.     RCHRES  10     INFLOW IVOL
PERLND   5 PWATER PERO           2080.     RCHRES  10     INFLOW IVOL
PERLND   6 PWATER PERO           1067.     RCHRES  10     INFLOW IVOL
PERLND   4 SEDMNT SOSED          1216.     RCHRES  10     INFLOW ISED   1
PERLND   4 SEDMNT SOSED          6080.     RCHRES  10     INFLOW ISED   2
PERLND   4 SEDMNT SOSED          4864.     RCHRES  10     INFLOW ISED   3
PERLND   5 SEDMNT SOSED          2496.     RCHRES  10     INFLOW ISED   1
PERLND   5 SEDMNT SOSED         12480.     RCHRES  10     INFLOW ISED   2
PERLND   5 SEDMNT SOSED          9984.     RCHRES  10     INFLOW ISED   3
PERLND   6 SEDMNT SOSED          7680.       RCHRES  10       INFLOW ISED   2
PERLND   6 SEDMNT SOSED          5120.       RCHRES  10       INFLOW ISED   3
PERLND   4 PEST   POPST  1       3648.       RCHRES  10       INFLOW IDQAL  1
PERLND   4 PEST   SOSDPS 1        438.       RCHRES  10       INFLOW ISQAL  2 1
PERLND   4 PEST   SOSDPS 1       3210.       RCHRES  10       INFLOW ISQAL  3 1
PERLND   5 PEST   POPST  1      12480.       RCHRES  10       INFLOW IDQAL  1
PERLND   5 PEST   SOSDPS 1       1498.       RCHRES  10       INFLOW ISQAL  2 1
PERLND   5 PEST   SOSDPS 1      10982.       RCHRES  10       INFLOW ISQAL  3 1
RCHRES  10 ROFLOW                 1.0        RCHRES   9       INFLOW
PERLND   4 PWATER PERO            587.       RCHRES   9       INFLOW IVOL
PERLND   5 PWATER PERO           1280.       RCHRES   9       INFLOW IVOL
PERLND   6 PWATER PERO            640.       RCHRES   9       INFLOW IVOL
PERLND   4 SEDMNT SOSED           704.       RCHRES   9       INFLOW ISED   1
PERLND   4 SEDMNT SOSED          3520.       RCHRES   9       INFLOW ISED   2
PERLND   4 SEDMNT SOSED          2816.       RCHRES   9       INFLOW ISED   3
PERLND   5 SEDMNT SOSED          1536.       RCHRES   9       INFLOW ISED   1
PERLND   5 SEDMNT SOSED          7680.       RCHRES   9       INFLOW ISED   2
PERLND   5 SEDMNT SOSED          6144.       RCHRES   9       INFLOW ISED   3
PERLND   6 SEDMNT SOSED          4608.       RCHRES   9       INFLOW ISED   2
PERLND   6 SEDMNT SOSED          3072.       RCHRES   9       INFLOW ISED   3
PERLND   4 PEST   POPST  1       2112.       RCHRES   9       INFLOW IDQAL  1
PERLND   4 PEST   SOSDPS 1        253.       RCHRES   9       INFLOW ISQAL  2 1
PERLND   4 PEST   SOSDPS 1       1859.       RCHRES   9       INFLOW ISQAL  3 1
PERLND   5 PEST   POPST  1       7680.       RCHRES   9       INFLOW IDQAL  1
PERLND   5 PEST   SOSDPS 1        922.       RCHRES   9       INFLOW ISQAL  2 1
PERLND   5 PEST   SOSDPS 1       6758.       RCHRES   9       INFLOW ISQAL  3 1
RCHRES   9 ROFLOW                 1.0        RCHRES   8       INFLOW
PERLND   4 PWATER PERO           5333.       RCHRES   8       INFLOW IVOL
PERLND   5 PWATER PERO          10190.       RCHRES   8       INFLOW IVOL
PERLND   6 PWATER PERO           4960.       RCHRES   8       INFLOW IVOL
PERLND   4 SEDMNT SOSED          6400.       RCHRES   8       INFLOW ISED   1
PERLND   4 SEDMNT SOSED         32000.       RCHRES   8       INFLOW ISED   2
PERLND   4 SEDMNT SOSED         25600.       RCHRES   8       INFLOW ISED   3
PERLND   5 SEDMNT SOSED         12224.       RCHRES   8       INFLOW ISED   1
PERLND   5 SEDMNT SOSED         61120.       RCHRES   8       INFLOW ISED   2
PERLND   5 SEDMNT SOSED         48896.       RCHRES   8       INFLOW ISED   3
PERLND   6 SEDMNT SOSED         35712.       RCHRES   8       INFLOW ISED   2
PERLND   6 SEDMNT SOSED         23808.       RCHRES   8       INFLOW ISED   3
PERLND   4 PEST   POPST  1      19200.       RCHRES   8       INFLOW IDQAL  1
PERLND   4 PEST   SOSDPS 1       2304.       RCHRES   8       INFLOW ISQAL  2 1
PERLND   4 PEST   SOSDPS 1      16896.       RCHRES   8       INFLOW ISQAL  3 1
PERLND   5 PEST   POPST  1      61120.       RCHRES   8       INFLOW IDQAL  1
PERLND   5 PEST   SOSDPS 1       7334.       RCHRES   8       INFLOW ISQAL  2 1
PERLND   5 PEST   SOSDPS 1      53786.       RCHRES   8       INFLOW ISQAL  3 1
RCHRES   8 ROFLOW                 1.0        RCHRES   7       INFLOW
PERLND   4 PWATER PERO           4053.       RCHRES   7       INFLOW IVOL
PERLND   5 PWATER PERO           9173.       RCHRES   7       INFLOW IVOL
PERLND   6 PWATER PERO           5867.       RCHRES   7       INFLOW IVOL
PERLND   4 SEDMNT SOSED          4864.       RCHRES   7       INFLOW ISED   1
PERLND   4 SEDMNT SOSED         24320.       RCHRES   7       INFLOW ISED   2
PERLND   4 SEDMNT SOSED         19456.       RCHRES   7       INFLOW ISED   3
PERLND   5 SEDMNT SOSED         11008.       RCHRES   7       INFLOW ISED   1
PERLND   5 SEDMNT SOSED         55040.       RCHRES   7       INFLOW ISED   2
PERLND   5 SEDMNT SOSED         44032.       RCHRES   7       INFLOW ISED   3
PERLND   6 SEDMNT SOSED         42240.       RCHRES   7       INFLOW ISED   2
PERLND   6 SEDMNT SOSED         28160.       RCHRES   7       INFLOW ISED   3
PERLND   4 PEST   POPST  1      14592.       RCHRES   7       INFLOW IDQAL  1
PERLND   4 PEST   SOSDPS 1       1751.       RCHRES   7       INFLOW ISQAL  2 1
PERLND   4 PEST   SOSDPS 1      12841.       RCHRES   7       INFLOW ISQAL  3 1
PERLND   5 PEST   POPST  1      55040.       RCHRES   7       INFLOW IDQAL  1
PERLND   5 PEST   SOSDPS 1       6605.       RCHRES   7       INFLOW ISQAL  2 1
PERLND   5 PEST   SOSDPS 1      48435.       RCHRES   7       INFLOW ISQAL  3 1
RCHRES   7 ROFLOW                 1.0        RCHRES   6       INFLOW
PERLND   1 PWATER PERO           2400.       RCHRES   6       INFLOW IVOL
PERLND   2 PWATER PERO           6933.       RCHRES   6       INFLOW IVOL
PERLND   3 PWATER PERO           5547.       RCHRES   6       INFLOW IVOL
PERLND   1 SEDMNT SOSED          1440.       RCHRES   6       INFLOW ISED   1
PERLND   1 SEDMNT SOSED         15840.       RCHRES   6       INFLOW ISED   2
PERLND   1 SEDMNT SOSED         11520.       RCHRES   6       INFLOW ISED   3
PERLND   2 SEDMNT SOSED          4160.       RCHRES   6       INFLOW ISED   1
PERLND   2 SEDMNT SOSED         45760.       RCHRES   6       INFLOW ISED   2
PERLND   2 SEDMNT SOSED         33280.       RCHRES   6       INFLOW ISED   3
PERLND   3 SEDMNT SOSED         39936.       RCHRES   6       INFLOW ISED   2
PERLND   3 SEDMNT SOSED         26624.       RCHRES   6       INFLOW ISED   3
PERLND   1 PEST   POPST  1       8640.       RCHRES   6       INFLOW IDQAL  1
PERLND   1 PEST   SOSDPS 1       1037.       RCHRES   6       INFLOW ISQAL  2 1
PERLND   1 PEST   SOSDPS 1       7603.       RCHRES   6       INFLOW ISQAL  3 1
PERLND   2 PEST   POPST  1      41600.       RCHRES   6       INFLOW IDQAL  1
PERLND   2 PEST   SOSDPS 1       4992.       RCHRES   6       INFLOW ISQAL  2 1
PERLND   2 PEST   SOSDPS 1      36608.       RCHRES   6       INFLOW ISQAL  3 1
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RCHRES   6 ROFLOW               1.0         RCHRES    5     INFLOW
PERLND   1 PWATER PERO          853.        RCHRES    5     INFLOW IVOL
PERLND   2 PWATER PERO         2027.        RCHRES    5     INFLOW IVOL
PERLND   3 PWATER PERO         2027.        RCHRES    5     INFLOW IVOL
PERLND   1 SEDMNT SOSED         512.        RCHRES    5     INFLOW ISED   1
PERLND   1 SEDMNT SOSED        5632.        RCHRES    5     INFLOW ISED   2
PERLND   1 SEDMNT SOSED        4096.        RCHRES    5     INFLOW ISED   3
PERLND   2 SEDMNT SOSED        1216.        RCHRES    5     INFLOW ISED   1
PERLND   2 SEDMNT SOSED       13376.        RCHRES    5     INFLOW ISED   2
PERLND   2 SEDMNT SOSED        9728.        RCHRES    5     INFLOW ISED   3
PERLND   3 SEDMNT SOSED       14592.        RCHRES    5     INFLOW ISED   2
PERLND   3 SEDMNT SOSED        9728.        RCHRES    5     INFLOW ISED   3
PERLND   1 PEST   POPST  1      3072.       RCHRES    5     INFLOW IDQAL  1
PERLND   1 PEST   SOSDPS 1       369.       RCHRES    5     INFLOW ISQAL  2 1
PERLND   1 PEST   SOSDPS 1      2703.       RCHRES    5     INFLOW ISQAL  3 1
PERLND   2 PEST   POPST  1     12160.       RCHRES    5     INFLOW IDQAL  1
PERLND   2 PEST   SOSDPS 1      1459.       RCHRES    5     INFLOW ISQAL  2 1
PERLND   2 PEST   SOSDPS 1     10701.       RCHRES    5     INFLOW ISQAL  3 1
RCHRES   5 ROFLOW               1.0         RCHRES    4     INFLOW
PERLND   1 PWATER PERO          960.        RCHRES    4     INFLOW IVOL
PERLND   2 PWATER PERO         2187.        RCHRES    4     INFLOW IVOL
PERLND   3 PWATER PERO         2400.        RCHRES    4     INFLOW IVOL
PERLND   1 SEDMNT SOSED         576.        RCHRES    4     INFLOW ISED   1
PERLND   1 SEDMNT SOSED        6336.        RCHRES    4     INFLOW ISED   2
PERLND   1 SEDMNT SOSED        4608.        RCHRES    4     INFLOW ISED   3
PERLND   2 SEDMNT SOSED        1312.        RCHRES    4     INFLOW ISED   1
PERLND   2 SEDMNT SOSED       14432.        RCHRES    4     INFLOW ISED   2
PERLND   2 SEDMNT SOSED       10496.        RCHRES    4     INFLOW ISED   3
PERLND   3 SEDMNT SOSED       17280.        RCHRES    4     INFLOW ISED   2
PERLND   3 SEDMNT SOSED       11520.        RCHRES    4     INFLOW ISED   3
PERLND   1 PEST   POPST  1      3456.       RCHRES    4     INFLOW IDQAL  1
PERLND   1 PEST   SOSDPS 1       415.       RCHRES    4     INFLOW ISQAL  2 1
PERLND   1 PEST   SOSDPS 1      3041.       RCHRES    4     INFLOW ISQAL  3 1
PERLND   2 PEST   POPST  1     13120.       RCHRES    4     INFLOW IDQAL  1
PERLND   2 PEST   SOSDPS 1      1574.       RCHRES    4     INFLOW ISQAL  2 1
PERLND   2 PEST   SOSDPS 1     11546.       RCHRES    4     INFLOW ISQAL  3 1
RCHRES   4 ROFLOW               1.0         RCHRES    3     INFLOW
PERLND   1 PWATER PERO         1227.        RCHRES    3     INFLOW IVOL
PERLND   2 PWATER PERO         2880.        RCHRES    3     INFLOW IVOL
PERLND   3 PWATER PERO         3200.        RCHRES    3     INFLOW IVOL
PERLND   1 SEDMNT SOSED         736.        RCHRES    3     INFLOW ISED   1
PERLND   1 SEDMNT SOSED        8096.        RCHRES    3     INFLOW ISED   2
PERLND   1 SEDMNT SOSED        5888.        RCHRES    3     INFLOW ISED   3
PERLND   2 SEDMNT SOSED        1728.        RCHRES    3     INFLOW ISED   1
PERLND   2 SEDMNT SOSED       19008.        RCHRES    3     INFLOW ISED   2
PERLND   2 SEDMNT SOSED       13824.        RCHRES    3     INFLOW ISED   3
PERLND   3 SEDMNT SOSED       23040.        RCHRES    3     INFLOW ISED   2
PERLND   3 SEDMNT SOSED       15360.        RCHRES    3     INFLOW ISED   3
PERLND   1 PEST   POPST  1      4416.       RCHRES    3     INFLOW IDQAL  1
PERLND   1 PEST   SOSDPS 1       530.       RCHRES    3     INFLOW ISQAL  2 1
PERLND   1 PEST   SOSDPS 1      3886.       RCHRES    3     INFLOW ISQAL  3 1
PERLND   2 PEST   POPST  1     17280.       RCHRES    3     INFLOW IDQAL  1
PERLND   2 PEST   SOSDPS 1      2074.       RCHRES    3     INFLOW ISQAL  2 1
PERLND   2 PEST   SOSDPS 1     15206.       RCHRES    3     INFLOW ISQAL  3 1
RCHRES   3 ROFLOW               1.0         RCHRES    2     INFLOW
PERLND   1 PWATER PERO         2880.        RCHRES    2     INFLOW IVOL
PERLND   2 PWATER PERO         6827.        RCHRES    2     INFLOW IVOL
PERLND   3 PWATER PERO         7733.        RCHRES    2     INFLOW IVOL
PERLND   1 SEDMNT SOSED        1728.        RCHRES    2     INFLOW ISED   1
PERLND   1 SEDMNT SOSED       19008.        RCHRES    2     INFLOW ISED   2
PERLND   1 SEDMNT SOSED       13824.        RCHRES    2     INFLOW ISED   3
PERLND   2 SEDMNT SOSED        4096.        RCHRES    2     INFLOW ISED   1
PERLND   2 SEDMNT SOSED       45056.        RCHRES    2     INFLOW ISED   2
PERLND   2 SEDMNT SOSED       32768.        RCHRES    2     INFLOW ISED   3
PERLND   3 SEDMNT SOSED       55680.        RCHRES    2     INFLOW ISED   2
PERLND   3 SEDMNT SOSED       37120.        RCHRES    2     INFLOW ISED   3
PERLND   1 PEST   POPST  1     10368.       RCHRES    2     INFLOW IDQAL  1
PERLND   1 PEST   SOSDPS 1      1244.       RCHRES    2     INFLOW ISQAL  2 1
PERLND   1 PEST   SOSDPS 1      9124.       RCHRES    2     INFLOW ISQAL  3 1
PERLND   2 PEST   POPST  1     40960.       RCHRES    2     INFLOW IDQAL  1
PERLND   2 PEST   SOSDPS 1      4915.       RCHRES    2     INFLOW ISQAL  2 1
PERLND   2 PEST   SOSDPS 1     36045.       RCHRES    2     INFLOW ISQAL  3 1
RCHRES   2 ROFLOW               1.0         RCHRES    1     INFLOW
PERLND   1 PWATER PERO         2293.        RCHRES    1     INFLOW IVOL
PERLND   2 PWATER PERO         6613.        RCHRES    1     INFLOW IVOL
PERLND   3 PWATER PERO         8800.        RCHRES    1     INFLOW IVOL
PERLND   1 SEDMNT SOSED        1376.        RCHRES    1     INFLOW ISED   1
PERLND   1 SEDMNT SOSED       15136.        RCHRES    1     INFLOW ISED   2
PERLND   1 SEDMNT SOSED       11008.        RCHRES    1     INFLOW ISED   3
PERLND   2 SEDMNT SOSED        3968.        RCHRES    1     INFLOW ISED   1
PERLND   2 SEDMNT SOSED       43648.        RCHRES   1     INFLOW ISED   2
PERLND   2 SEDMNT SOSED       31744.        RCHRES   1     INFLOW ISED   3
PERLND   3 SEDMNT SOSED       63360.        RCHRES   1     INFLOW ISED   2
PERLND   3 SEDMNT SOSED       42240.        RCHRES   1     INFLOW ISED   3
PERLND   1 PEST   POPST   1     8256.       RCHRES   1     INFLOW IDQAL  1
PERLND   1 PEST   SOSDPS  1       991.      RCHRES   1     INFLOW ISQAL  2 1
PERLND   1 PEST   SOSDPS  1     7265.       RCHRES   1     INFLOW ISQAL  3 1
PERLND   2 PEST   POPST   1    39680.       RCHRES   1     INFLOW IDQAL  1
PERLND   2 PEST   SOSDPS  1     4762.       RCHRES   1     INFLOW ISQAL  2 1
PERLND   2 PEST   SOSDPS  1    34918.       RCHRES   1     INFLOW ISQAL  3 1
RCHRES  13 HYDR   ROVOL       6.05          PLTGEN   1     INPUT  MEAN   1
RCHRES   7 HYDR   ROVOL       6.05          PLTGEN   2     INPUT  MEAN   1
RCHRES   1 HYDR   ROVOL       6.05          PLTGEN   3     INPUT  MEAN   1
RCHRES   1 SEDTRN ROSED   4 1 1.118E-3      PLTGEN   4     INPUT  MEAN   1
RCHRES   1 HYDR   ROVOL       6.711E-6      DISPLY   1     INPUT  TIMSER
RCHRES   1 SEDTRN ROSED   4 1 1.118E-3      DISPLY   3     INPUT  TIMSER
RCHRES  13 HYDR   ROVOL       6.05          DISPLY   5     INPUT  TIMSER
RCHRES   7 HYDR   ROVOL       6.05          DISPLY   7     INPUT  TIMSER
RCHRES   1 HYDR   ROVOL       6.05          DISPLY   9     INPUT  TIMSER
PERLND   1 SEDMNT SOSED       2000.         DISPLY  11     INPUT  TIMSER
PERLND   2 SEDMNT SOSED       2000.         DISPLY  12     INPUT  TIMSER
PERLND   3 SEDMNT SOSED       2000.         DISPLY  13     INPUT  TIMSER
PERLND   4 SEDMNT SOSED       2000.         DISPLY  14     INPUT  TIMSER
PERLND   5 SEDMNT SOSED       2000.         DISPLY  15     INPUT  TIMSER
PERLND   6 SEDMNT SOSED       2000.         DISPLY  16     INPUT  TIMSER
PERLND   7 SEDMNT SOSED       2000.         DISPLY  17     INPUT  TIMSER
PERLND   8 SEDMNT SOSED       2000.         DISPLY  18     INPUT  TIMSER
PERLND   9 SEDMNT SOSED       2000.         DISPLY  19     INPUT  TIMSER
RCHRES   7 GQUAL  DQAL                      DISPLY  20     INPUT  TIMSER
RCHRES   7 GQUAL  RODQAL  1 1 1.026E-6      DISPLY  21     INPUT  TIMSER
RCHRES   7 GQUAL  ROSQAL  4 1               GENER    1     INPUT  ONE
RCHRES   7 SEDTRN ROSED   4 1               GENER    1     INPUT  TWO
GENER    1 OUTPUT TIMSER        500.        DISPLY  22     INPUT  TIMSER
RCHRES   7 GQUAL  ROSQAL  4 1 1.026E-6      DISPLY  23     INPUT  TIMSER
RCHRES   1 GQUAL  DQAL                      DISPLY  24     INPUT  TIMSER
RCHRES   1 GQUAL  RODQAL  1 1 5.592E-7      DISPLY  25     INPUT  TIMSER
RCHRES   1 GQUAL  ROSQAL  4 1               GENER    2     INPUT  ONE
RCHRES   1 SEDTRN ROSED   4 1               GENER    2     INPUT  TWO
GENER    2 OUTPUT TIMSER        500.        DISPLY  26     INPUT  TIMSER
RCHRES   1 GQUAL  ROSQAL  4 1 5.592E-7      DISPLY  27     INPUT  TIMSER
RCHRES   7 GQUAL  DQAL                      PLTGEN   5     INPUT  POINT  1
RCHRES   1 GQUAL  DQAL                      PLTGEN   5     INPUT  POINT  2
GENER    1 OUTPUT TIMSER        500.        PLTGEN   6     INPUT  MEAN   1
GENER    2 OUTPUT TIMSER        500.        PLTGEN   6     INPUT  MEAN   2
RCHRES   7 GQUAL  RODQAL  1 1 1.026E-6      PLTGEN   7     INPUT  MEAN   1
RCHRES   1 GQUAL  RODQAL  1 1 5.592E-7      PLTGEN   7     INPUT  MEAN   2
RCHRES   7 GQUAL  ROSQAL  4 1 1.026E-6      PLTGEN   8     INPUT  MEAN   1
RCHRES   1 GQUAL  ROSQAL  4 1 5.592E-7      PLTGEN   8     INPUT  MEAN   2
END NETWORK

END RUN
/*
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL1.IOWA.PEST.C2,
//        DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL2.IOWA.PEST.C2,
//        DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL3.IOWA.PEST.C2,
//        DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL4.IOWA.PEST.C2,
//        DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL5.IOWA.PEST.C2,
//        DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL6.IOWA.PEST.C2,
//        DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//          REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL7.IOWA.PEST.C2,
//         DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
// EXEC FORTGO,PROG=PLOT,LIB='WYL.XA.R72.PLOT',VOL=PUB010,
//           REGION.GO=512K
//GO.FT05F001 DD DSN=WYL.XA.R72.PLOTFL8.IOWA.PEST.C2,
//         DISP=(OLD,KEEP),UNIT=DISK,VOL=SER=PUB010
```

APPENDIX B

Use of the NETWORK Block to Connect the Surface and Instream Application Modules

In HSPF, the operational connection between the land surface and instream simulation modules is accomplished through the NETWORK Block. Time series of runoff, sediment, and pollutant loadings generated on the land surface are passed to the receiving stream for subsequent transport and transformation simulation. This connection of the IMPLND and/or PERLND modules with the RCHRES module requires explicit definition of corresponding time series in the linked modules. A one-to-one correspondence exists between several land segment outflow time series and corresponding stream reach inflow time series (e.g. runoff, sediment, dissolved oxygen, etc.); however in order to maintain flexibility, some of the time series are more general, and no unique correspondence exists. Also, in some cases, a process or material simulated in the stream will have no corresponding land surface quantity. For example, the inflow of plankton to a stream occurs only from upstream reaches and not from a land segment.

The following table is a list of the more common or likely time series correspondences between the IMPLND/PERLND modules and RCHRES. The table is structured such that the right hand section consists of a list of all possible materials or quantities simulated in the RCHRES module. Information included for each is the HSPF section in which the material is simulated, the variable name, and its units. The left hand column indicates the corresponding time series from the land segment module (or a possible one) and includes the same information as the right side. In addition, a conversion (CONV FACTOR) factor between the two corresponding time series is specified. The actual multiplication factor (MFACT) to be used in the NETWORK Block is calculated as: MFACT = area * CONV. FACTOR. The user should note that the module sections PQUAL, IQUAL, and GQUAL involve the simulation of one or more general quality constituents; consequently, their inclusion in these tables reflects only possible or recommended correspondence. Other combinations are possible depending on the particular application. The user should consult the individual time series catalogs (Part F, Section 4.7 of the User's Manual) for more detailed information about particular time series.

CORRESPONDENCE BETWEEN PERLND OUTPUT TIME SERIES AND RCHRES INPUT TIME SERIES
(ENGLISH UNITS-USE CONV FACTOR * AREA (IN ACRES) FOR MFACT)

PERLND MODULE						RCHRES MODULE				
SECTION	#	VARIABLE	SUBS	UNITS	CONV FACTOR	SECTION	#	VARIABLE	SUBS	UNITS
PWATER	3	PERO	1 1	in/ivl	0.0833	HYDR	1	IVOL	1 1	acft/ivl
PQUAL	7	POQUAL	1 1	qty/acivl	1.0	CONS	2	ICON	1 1	qty/ivl
PWTGAS	6	POHT	1 1	BTU/acivl	1.0	HTRCH	3	IHEAT	1 1	BTU/ivl
SEDMNT	4	SOSED	1 1	ton/acivl	frac sand	SEDTRN	4	ISED	1 1	ton/ivl
SEDMNT	4	SOSED	1 1	ton/acivl	frac silt	SEDTRN	4	ISED	2 1	ton/ivl
SEDMNT	4	SOSED	1 1	ton/acivl	frac clay	SEDTRN	4	ISED	3 1	ton/ivl
PEST	9	POPST	1 1	lbs/acivl	1.0	GQUAL	5	IDQAL	1 1	qty/ivl
PEST	9	SOSDPS	1 1	lbs/acivl	frac on sand	GQUAL	5	ISQAL	1 1	qty/ivl
PEST	9	SOSDPS	1 1	lbs/acivl	frac on silt	GQUAL	5	ISQAL	2 1	qty/ivl
PEST	9	SOSDPS	1 1	lbs/acivl	frac on clay	GQUAL	5	ISQAL	3 1	qty/ivl
PWTGAS	6	PODOXM	1 1	lbs/acivl	1.0	OXRX	6	OXIF	1 1	lbs/ivl
PQUAL	7	POQUAL	1 1	qty/acivl	1.0	OXRX	6	OXIF	2 1	lbs/ivl
NITR	10	PONO3	1 1	lbs/acivl	1.0	NUTRX	7	NUIF	1 1	lbs/ivl
NITR	10	PONH4	1 1	lbs/acivl	1.0	NUTRX	7	NUIF	2 1	lbs/ivl
PQUAL	7	POQUAL	1 1	qty/acivl	1.0	NUTRX	7	NUIF	3 1	lbs/ivl
PHOS	11	TSP4S	1 1	lbs/acivl	1.0	NUTRX	7	NUIF	4 1	lbs/ivl
PHOS	11	TSP4S	5 1	lbs/acivl	1.0	NUTRX	7	NUIF	4 1	lbs/ivl
PHOS	11	SSP4S	3 1	lbs/acivl	1.0	NUTRX	7	NUIF	4 1	lbs/ivl
PHOS	11	SEDP	2 1	lbs/acivl	1.0	NUTRX	7	NUIF	4 1	lbs/ivl
						PLANK	8	PKIF	1 1	lbs/ivl
						PLANK	8	PKIF	2 1	lbs/ivl
NITR	10	SEDN	1 1	lbs/acivl	1.0	PLANK	8	PKIF	3 1	lbs/ivl
PHOS	11	SEDP	1 1	lbs/acivl	1.0	PLANK	8	PKIF	4 1	lbs/ivl
PQUAL	7	POQUAL	1 1	qty/acivl	1.0	PLANK	8	PKIF	5 1	lbs/ivl
PQUAL	7	POQUAL	1 1	qty/acivl	1.0	PHCARB	9	PHIF	1 1	lbs/ivl
PWTGAS	6	POCO2M	1 1	lbs/acivl	1.0	PHCARB	9	PHIF	2 1	lbs/ivl

Notes:

(1) in the NETWORK Block, the RCHRES target group specification (TGRPN) is INFLOW.

(2) PERLND total NH4(solution + adsorbed) enters RCHRES as solution NH3.

(3) PERLND total PO4(solution + adsorbed) enters RCHRES as solution PO4.

(4) no entries in PERLND columns indicate no contribution from PERLND for corresponding RCHRES component.

(5) distribution of sediment and pesticide associated with sediment into SAND, SILT and CLAY requires estimation of constant size fraction distributions.

(6) "qty" is a user-specified unit, and should be defined the same as in the corresponding time series

CORRESPONDENCE BETWEEN IMPLND OUTPUT TIME SERIES AND RCHRES INPUT TIME SERIES
(ENGLISH UNITS-USE CONV FACTOR * AREA (IN ACRES) FOR MFACT)

IMPLND MODULE						RCHRES MODULE				
SECTION	#	VARIABLE	SUBS	UNITS	CONV FACTOR	SECTION	#	VARIABLE	SUBS	UNITS
IWATER	3	SURO	1 1	in/ivl	0.0833	HYDR	1	IVOL	1 1	acft/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	CONS	2	ICON	1 1	qty/ivl
IWTGAS	5	SOHT	1 1	BTU/acivl	1.0	HTRCH	3	IHEAT	1 1	BTU/ivl
SOLIDS	4	SOSLD	1 1	ton/acivl	frac sand	SEDTRN	4	ISED	1 1	ton/ivl
SOLIDS	4	SOSLD	1 1	ton/acivl	frac silt	SEDTRN	4	ISED	2 1	ton/ivl
SOLIDS	4	SOSLD	1 1	ton/acivl	frac clay	SEDTRN	4	ISED	3 1	ton/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	GQUAL	5	IDQAL	1 1	qty/ivl
IQUAL	6	SOQS	1 1	qty/acivl	frac on sand	GQUAL	5	ISQAL	1 1	qty/ivl
IQUAL	6	SOQS	1 1	qty/acivl	frac on silt	GQUAL	5	ISQAL	2 1	qty/ivl
IQUAL	6	SOQS	1 1	qty/acivl	frac on clay	GQUAL	5	ISQAL	3 1	qty/ivl
IWTGAS	5	SODOXM	1 1	lbs/acivl	1.0	OXRX	6	OXIF	1 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	OXRX	6	OXIF	2 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	NUTRX	7	NUIF	1 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	NUTRX	7	NUIF	2 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	NUTRX	7	NUIF	3 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	NUTRX	7	NUIF	4 1	lbs/ivl
						PLANK	8	PKIF	1 1	lbs/ivl
						PLANK	8	PKIF	2 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	PLANK	8	PKIF	3 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	PLANK	8	PKIF	4 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	PLANK	8	PKIF	5 1	lbs/ivl
IQUAL	6	SOQO	1 1	qty/acivl	1.0	PHCARB	9	PHIF	1 1	lbs/ivl
IWTGAS	5	SOCO2M	1 1	lbs/acivl	1.0	PHCARB	9	PHIF	2 1	lbs/ivl

Notes:

(1) in the NETWORK Block, the RCHRES target group specification (TGRPN) is INFLOW.

(2) no entries in IMPLND columns indicate no contribution from IMPLND for corresponding RCHRES component.

(3) distribution of sediment and contaminant associated with sediment into SAND, SILT and CLAY requires estimation of constant size fraction distributions.

(4) "qty" is a user-specified unit, and should be defined the same as in the corresponding time series

APPENDIX C

Equivalency Table for Selected HSPF and ARM/NPS Model Parameter Names

HSPF and Corresponding ARM Model Parameters*

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Runoff-related			
Interception	CEPSC(M)	EPXM	Interception storage capacity. Values in ARM vary with monthly crop cover.
	-----	A	Impervious areas are handled as a separate segment in HSPF.
Depression/Surface Storage	UZSN(M)	UZSN	Upper Zone Nominal Moisture Capacity.
Soil Moisture Storage	LZSN	LZSN	Lower Zone Nominal Moisture Capacity.
Overland Flow	LSUR	L	Length of overland flow path.
	SLSUR	SS	Slope of overland flow path.
	NSUR(M)	NN	Manning's n of overland flow path.
Infiltration	INFILT	INFIL	Index to infiltration capacity of soil.
	INFEXP	none	Exponent in infiltration equation. Value of 2.0 is used in ARM.
	INFILD	none	Ratio of max to mean infiltration capacities of the soil. Value of 2.0 is used in ARM.
Subsurface Flow	INTFW(M)	INTER	Interflow inflow parameter.
	IRC(M)	IRC	Interflow recession parameter.
	DEEPFR	K24L	Fraction of groundwater inflow to deep aquifers.
	AGWRC	KK24	Groundwater recession parameter.
	KVARY	KV	Variable groundwater recession parameter.

* : Parameters followed by '(M)' indicate that 12 monthly values can be specified.

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Evapotranspiration	LZETP(M)	K3(M)	Lower zone ET parameter.
	-----	PETMUL	Time series adjustments are made with MFACT in the NETWORK Block.
	FOREST	-----	Fraction of PLS covered by forest which will continue to transpire in winter. Not in ARM Model.
	AGWETP	K24EL	Evapotranspiration parameter for groundwater storage.
	BASETP	-----	Evapotranspiration from baseflow. Not in ARM Model.
Snowmelt-related			
Gage Efficiency	SNOWCF	SCF	Snow catch parameter to account for poor catch efficiency of gage.
Melt Processes	CCFACT	CCFAC	Adjustment factor for condensation-convection melt equation.
	------	RADCON, RMUL	Adjustments to radiation melt and solar radiation time series are performed with MFACT in NETWORK Block of HSPF.
	MGMELT	DGM	Daily ground melt factor.
	PETMIN, PETMAX	PETMIN, PETMAX	These parameters are used in SNOW section of ARM, but are used in PWATER section of HSPF.

* : Parameters followed by '(M)' indicate that 12 monthly values can be specified.

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Snowpack Processes	RDCNS	IDNS	Snow density of new snow.
	MWATER	WC	Maximum water content of pack.
	SNOEVP	EVAPSN	Snow evaporation factor.
	TSNOW	TSNOW	Snow/rain determination temperature.
Watershed Characteristics	ELDAT	ELDIF	Elevation difference between gage and watershed. ELDAT is in feet (meters) and is used in ATEMP section of HSPF.
	SHADE	F	Forest cover fraction.
	LAT	-----	Watershed latitude used to define winter and summer periods for Albedo calculations.
	MELEV	MELEV	Mean watershed elevation.
	-----	KUGI, WMUL	These parameters to adjust wind data are not in HSPF. Time series adjustments in HSPF are done with MFACT in the NETWORK Block.
	COVIND	MPACK	Water equivalent of snowpack for complete areal coverage.

* : Parameters followed by '(M)' indicate that 12 monthly values can be specified.

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Sediment-related			
Detachment by Rainfall	COVER(M)	COVPMO(M)	Monthly crop canopy parameter.
	KRER	KRER	Coefficient in soil detachment equation.
	JRER	JRER	Exponent in soil detachment equation.
	SMPF	SMPF	Supporting management practice factor.
Detachment/scour by overland flow	KGER	none	Coefficient in matrix soil scour equation.
	JGER	none	Exponent in matrix soil scour equation.
Transport by overland flow	KSER	KSER	Coefficient in sediment transport equation.
	JSER	JSER	Exponent in sediment transport equation.
Delivery to stream	No specific parameter		
Gully Erosion/scour	KGER JGER	none none	Gullying is included in the soil scour equation.
Availability/Production of soil fines	DETS	SRERTL	Soil fines produced by tillage.
Aggregation/Compaction	AFFIX	SCMPAC	Daily reduction in detached soil fines due to compaction/ settling.
	NVSI(M)	none	Daily atmospheric accumulation/ removal of soil fines (positive or negative)

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Chemical-related			
Availability/Input (Surface & Sub-surface)	Note: Chemical applications are represented in HSPF by incrementing the storage values shown below by the application rate at the time of application.		
Pesticides	SPS(3) UPS(3) IPS(3) LPS(3) APS(3)	PSSZ PSUZ none PSLZ PSGC	Pesticide storages in surface (S), upper (U), interflow (I), lower (L), and groundwater (A or G) zones. HSPF allows for crystalline, adsorbed, and solution states in all but interflow.
Nitrogen	SN(5) UN(5) IN(2) LN(5) AN(5)	Storages are specified for each form in each soil layer except interflow	Five N forms (OrgN, NH3-A, NH3-S, NO3, PLANT-N) are specified for each layer, except that interflow has only NO3 and solution NH3.
Phosphorus	SP(4) UP(4) IP(1) LP(4) AP(4)	(analagous to nitrogen)	Four P forms (Org P, PO4-A, PO4-S, PLANT-P) are specified for each layer and only PO4-S for interflow storage
Transformations			
Nitrogen	KDSAM KADAM KIMNI KAM KDNI	KAS KSA KKIM KAM KD	NH3 desorption NH3 adsorption NO3 immobilization Org N ammonification Denitrification

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Transformations			
Nitrogen	KNI	K1	Nitrification
	KIMAM	KIM	NH3 immobilization
	NO3UTF	none	Fraction of plant uptake from NO3 and NH4; sum is equal to 1.0.
	NH4UTF	none	
	THKDSAM	THKAS	Temperature correction (THETA) values for each reaction designated by TH in front of the reaction name.
	etc.	etc.	
	CMAX	none	HSPF allows option to use Freundlich equilibrium calculations for NH3 adsorption instead of 1st order kinetics. These parameters are the solubility, irreversible adsorption, K, and N values.
	XFIX	none	
	K1	none	
	N1	none	
Phosphorus	KDSP	KAS	PO4 desorption
	KADP	KSA	PO4 adsorption
	KIMP	KIM	PO4 immobilization
	KMP	KM	Org P mineralization
	THKDSP	THKAS	Temperature correction (THETA) values for each reaction rate
	etc.	etc.	
	CMAX	none	(See note above for corres. nitrogen parameters.
	XFIX	none	
	K1	none	
	N1	none	

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Uptake/Degradation			
Pesticides	SDGCON UDGCON LDGCON ADGCON	KDG KDG KDG KDG	HSPF allows different degradation rates for each soil layer, surface (S), upper (U), lower (L), and groundwater (A)
Nitrogen	KPLNM(M)	KPL, ULUPTK LZUPTK	Plant uptake of nitrogen. HSPF allows monthly rates for each soil layer.
Phosphorus	KPLPM(M)	KPL, ULUPTK LZUPTK	Plant uptake of PO4. HSPF allows monthly rates for each soil layer.
Pesticide Adsorption/ Desorption	CMAX	CMAX	Maximum solubility
	XFIX	DD	Pesticide permanently fixed to soil.
	K1	K	Freundlich K value
	N1	N	Freundlich N value
	N2	NP	Freundlich N value for non-single-valued adsorp./desorp. option. Note:. HSPF allows these parameters to vary with each soil layer.
	KDSPS KADPS	none	1st order rate parameters for pesticide adsorption/desorption. This is an additional option in HSPF.
	THDSPS THADPS	none none	Temperature correction (THETA) values for pesticide 1st order A/D rates.

HSPF and Corresponding ARM Model Parameters (continued)

PROCESS	HSPF PARAMETER	CORRESPONDING ARM PARAMETER	COMMENT
Other			
Soil Temperature	ASLT(M) BSLT(M)	ASZT BSZT	Intercept (ASLT) and slope (BSLT) of surface layer temperature regression equation related to air temperature.
	ULTP1(M) ULTP2(M)	AUZT BUZT	Intercept (ULTP1) and slope (ULTP2) of upper layer soil temperature regression equation.
	Note: In HSPF, upper layer soil temperature can be modeled with a regression equation as defined above or with a smoothing algorithm with parameters redefined as follows:		
	ULTP1(M)	none	Smoothing factor
	ULTP2(M)	none	Mean difference between soil and air temperatures.
	LGTP1(M)	LZTEMP(M)	Monthly lower and groundwater layer temperatures at start of each month.
	Note: The smoothing algorithm option is also available for the lower and groundwater layers with the following parameters:		
	LGTP1(M)	none	Smoothing factor
	LGTP2(M)	none	Mean departure from lower/ groundwater soil temperature and air temperature.
Soil Depths	Surface Layer Upper Layer Lower Layer GW Layer	SZDPTH UZDPTH none none	Thickness of the assumed soil layers. In ARM,the lower layer is 6 feet, and UZDPTH is the total depth from the surface to the bottom of the upper layer.
Bulk Densities	Surface Layer Upper Layer Lower Layer GW Layer	BDSZ BDUZ BDLZ none	Bulk densities for each soil layer. HSPF does not assign a name to the bulk density or soil depth parameters.

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